SEPTEMBER 18, 1961

missiles and rockets

THE MISSILE/SPACE WEEKLY

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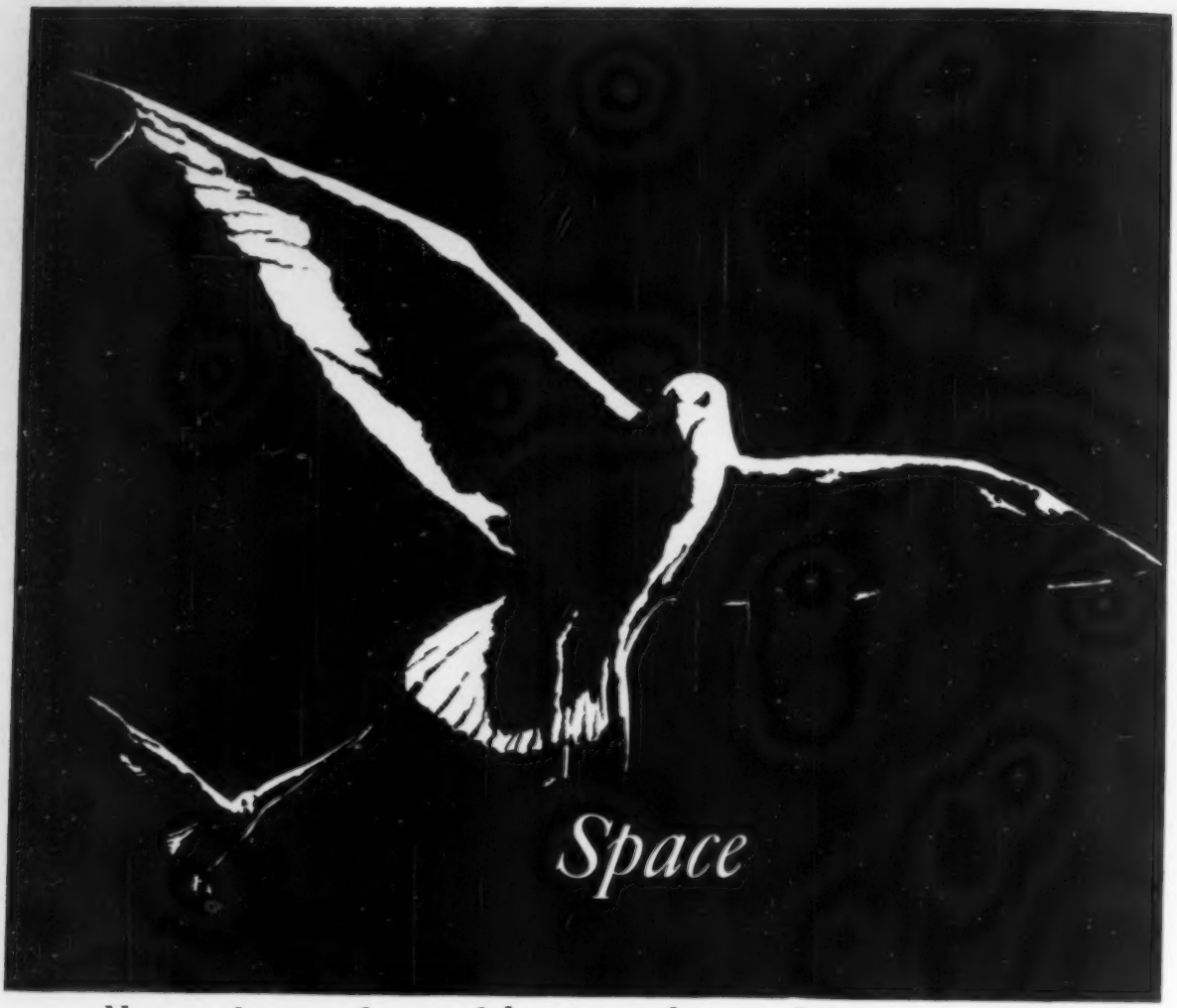

...roll on through pathless realms of space...Gilbert

The Range Planning Department of Pan Am's Guided Missiles Range Division is increasing its technical staff to meet the demands of the accelerated space progress, as a part of a well-organized systematic expansion program.

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missiles and rockets

Volume 9, Number 12 September 18, 1961

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THE COVER

Takeoff of a lunar probe vehicle in this conception by Martin Electronics Division gives indication of massive GSE needed for coming space launchings. *See p. 18.*

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letters

SLAM's Future

To the Editor:

CONGRATULATIONS ON THE VERY FINE SEPT. 4 EDITORIAL ("SLAM: TIME TO FISH OR CUT BAIT"). YOUR APPRAISAL OF THE SLAM PROGRAM IS BOTH ACCURATE AND TIMELY.

W. J. Hesse
Chance Vought Corp.
Dallas

Ski-launch Reopened

To the Editor:

I have been following your Letters section expecting to see an answer to the question raised in the letter from Mr. Lucien Greif (M/R, Aug. 21, p. 7), namely, would not a missile launched by the rumored Russian ski-launch system (Letters, M/R, July 31, p. 6) lose all of the kinetic energy in going up hill that it had gained in going downhill?

It would, of course, if allowed to go up as far as it originally came down, and nothing would be gained in such a launch if the rocket motor were not fired until it came to a stop. The object, however, would be to fire the rocket motor at its point of greatest speed, because the efficiency of such a motor would then be maximum. In fact, the efficiency of a rocket motor is zero at the time of launch (if the missile is not moving) and reaches 100% when the missile's velocity just equals the exhaust velocity of the gases. That is one reason why the second stage of a missile, carrying far less propellant than its first-stage booster, can gain more in velocity than that imparted to it by the first stage.

David Fulton, President
Hydro-Space Technology, Inc.
West Caldwell, N.J.

Hypervelocity Tunnels

To the Editor:

Mr. Reed Bundy's article on R&D in the Princeton area ("Princeton Climate Spurs Research," M/R, Aug. 21, p. 32), including the very important contributions on missile/space research by Princeton University's Gas Dynamics Laboratory, was well written and comprehensive.

However, I'm sure Prof. Bogdonoff and his associates at the Laboratory will not object to one correction in the article.

Specifically, the statement "It (the laboratory) has also supplied invaluable knowledge of gas dynamics—including the *only available performance data* on speeds from Mach 15 to Mach 20."

As a spokesman for the Arnold Center I concur completely that the Princeton group has provided a great fund of invaluable data, but I question the latter part of the statement. For the past three or four years we at the Arnold Engineering Development Center have had in operation two arc-driven wind tunnels providing information in the Mach 16 to 21 area. These have 16- and 50-inch-diameter test sections, respectively; and a third with a 100-inch test section is beginning shakedown operations. . . . These are part of the Center's von Karman Gas Dynamics Facility and were developed by the Center's Operating Contractor, ARO, Inc.

By the way, your article "Arnold Center Tests All Big Systems" (M/R, Aug. 14, p. 31) was greatly appreciated. Mr. James Trainor did a commendable job in describing the Mach 15-20 (16-21) Tunnels on p. 34.

Leon S. Jablecki, Colonel, USAF
DCS/Operations
Arnold Engineering Development Center, Tenn.

M/R erred in saying "only available performance data" on Mach 15-20 speeds; the mistake was the writer's not the university's. However, it should be noted that Princeton's helium tunnel can be run for as long as 10 minutes, whereas the "hot-shot" nitrogen tunnels at Arnold have a 100-millisecond limit.—Ed.

Spaceware & Earthenware?

To the Editor:

Ref COUNTDOWN item, M/R, Aug. 28, p. 9, titled "New Products Names Dept." (reporting that the Air Force is distinguishing between equipment and incorporeal products by applying the names "hardware" and "software"): And I suppose the Navy is working on "Surfaceware" and "Underware"—This could go on and on!

W. A. Koch
Aberdeen Proving Ground, Md.

Concerning STL

In our story "Will Congress Regulate 'Non-profits'?" (M/R, Aug. 28, p. 12), Space Technology Laboratories, Inc., was listed, with "non-profit" organizations, in a box showing firms under contract to the Air Force for research and development.

Some readers inferred from this that we were indicating STL as a "non-profit" corporation. This, of course, is not true. STL, a subsidiary of Thompson Ramo Wooldridge Inc., is a private enterprise corporation. It is financed wholly by private investors and operates under the same conditions as any other competitive industrial company.

It was, in fact, congressional criticism of possible "conflict of interest" in the relationship between STL, TRW and the Air Force that led to establishment of the "non-profit" Aerospace Corp.

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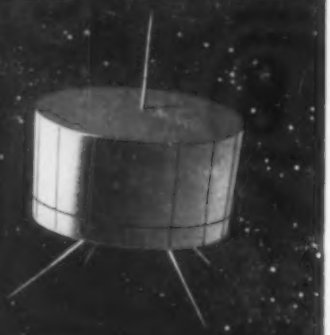

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—when and where—

SEPTEMBER

10th Annual Industrial Electronics Symposium, IRE, Bradford Hotel, Boston, Sept. 20-21.

AEC Welding Forum, Annual Meeting (classified), Southwest Research Institute, Granada Hotel, San Antonio, Tex., Sept. 20-22.

Air Force Association's 1961 Convention and Aerospace Panorama, Convention Hall, Philadelphia, Sept. 21-24.

Industrial Building Exposition and Congress, New York Coliseum, New York City, Sept. 25-28.

National Fall Meeting, American Welding Society, Hotel Adolphus, Dallas, Tex., Sept. 25-28.

European Congress on Aviation Medicine, Paris, Sept. 26-30.

Manufacturing Chemists' Association, General Safety Committee Workshop, Niagara Falls, Canada, Sept. 27.

3rd Annual Missile Symposium, The Hyatt House, Seattle, Sept. 27-29.

OCTOBER

7th National Communications Symposium, IRE Professional Group on Communications Systems, Utica, N.Y., Oct. 2-4.

IRE Canadian Electronics Conference, Automotive Bldg., Exhibition Park, Toronto, Oct. 2-4.

XII International Astronautical Congress, hosted by American Rocket Society, Washington, D.C., Oct. 2-7.

8th Annual Science & Engineering Symposium, AFSC and Aerospace Research, Sheraton-Palace Hotel, San Francisco, Oct. 3-4.

9th Annual Human Engineering Institute, Stamford, Conn., Oct. 3-6.

American Society of Photogrammetry Semi-annual Convention, Biltmore Hotel, New York City, Oct. 4-6.

17th National Electronics Conference and Exhibition, International Amphitheatre, Chicago, Oct. 9-11.

National Aeronautic and Space Engineering and Manufacturing Meeting, sponsored by Society of Automotive Engineers, Hotel Ambassador, Los Angeles, Oct. 9-13.

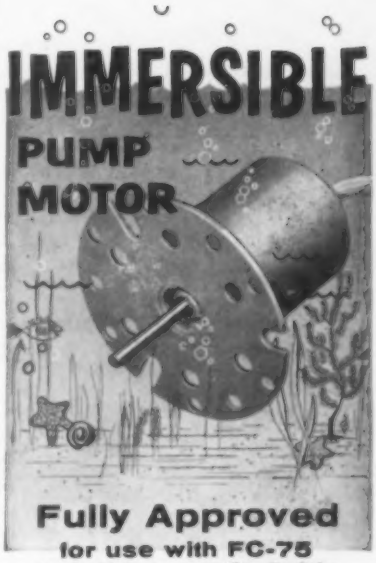
Space Flight Report to the Nation, American Rocket Society, New York Coliseum, New York City, Oct. 9-15.

Symposium on Shock, Vibration and Associated Environments, sponsored by DOD, Office of Director of R&E, Detroit, Oct. 10-12.

Optical Society of America Meeting, Somerset Hotel, Boston, Oct. 12-14.

17th Annual ISA Instrument-Automation Conference and Exhibit, New York Coliseum, New York City, Oct. 15-19.

Second International Congress, International Organization for Vacuum Science and Technology, Eighth Annual Symposium of the American Vacuum Society, Washington, D.C., Oct. 16-19.



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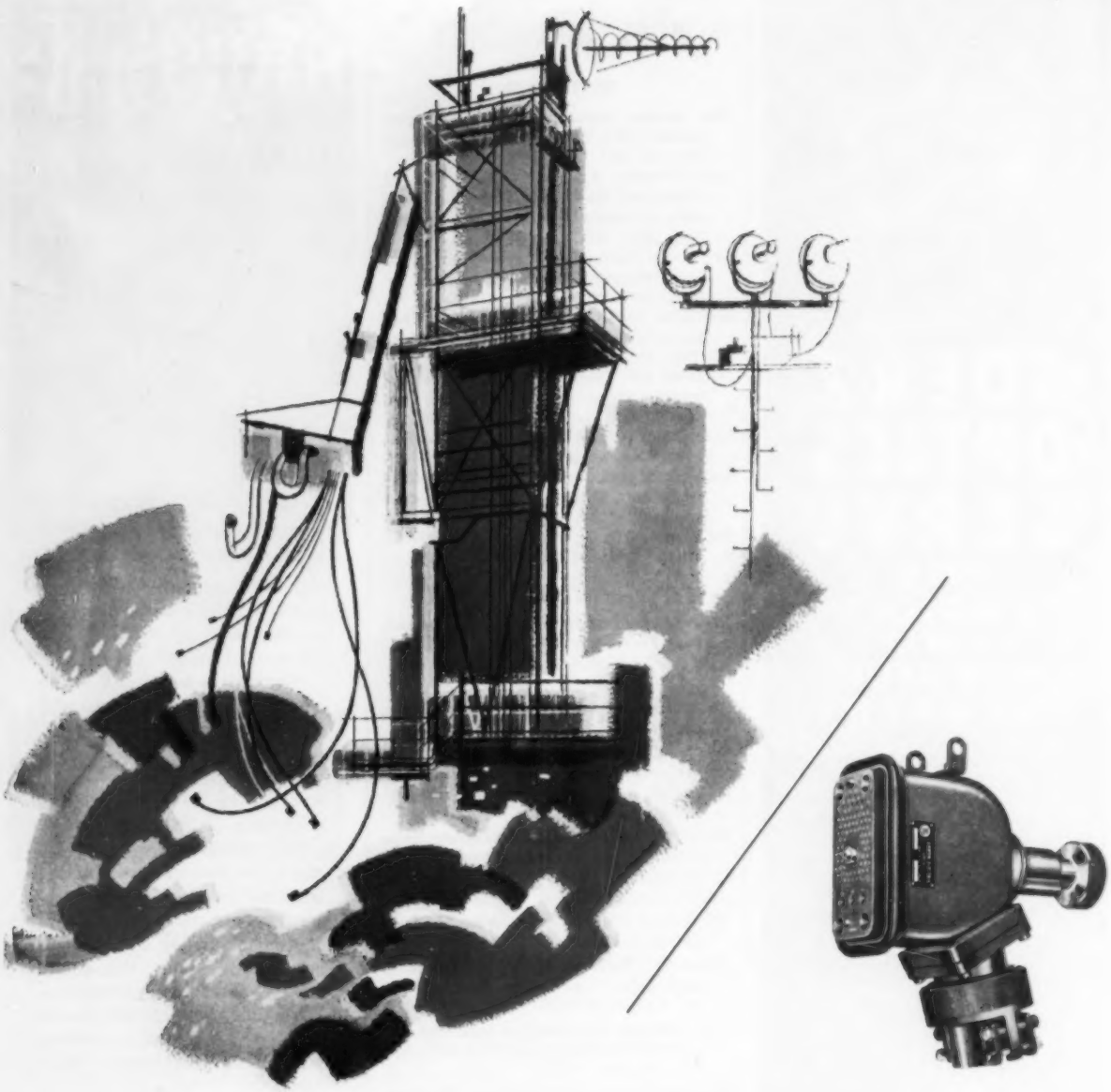

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The Countdown

WASHINGTON

Re-evaluating Minuteman

Soviet plans to develop a 100-megaton nuclear warhead are forcing some agonizing reappraisals of the strategic program packages submitted to the Defense Department for budget review. Among the key questions: Should hardening of fixed *Minuteman* sites be greatly increased (M/R, Sept. 11)? Have the mobile *Minuteman* and the mobile *Polaris* become more attractive than a large expansion of the planned number of fixed *Minuteman* squadrons?

Boosters on Capitol Hill

The Senate Space Committee's forthcoming hearings this month are aimed at shedding some light on NASA-DOD plans in the national space booster program. The committee wants to pinpoint where the plans for development of superboosters are heading—and how much they are going to cost.

Zeus at Pt. Mugu: No. 2

A second launching of *Nike-Zeus* from Pt. Mugu down the Pacific Missile Range is expected within about one month. The first flight on Sept. 9 was only partially successful, but it is not expected to cause any slippage in the test program. First tests from Kwajalein are expected early next year. Some observers are now betting on nuclear-warhead tests with *Zeus* before 1962 is out.

No Pad Slip for Samos

Damage to the *Atlas-Agena* launching pad at Pt. Arguello caused by the explosion in the Sept. 9 *Samos* launching attempt is not as extensive as first believed. Moreover, a second pad is available and others are under construction. Therefore, no slippage because of a pad shortage is expected.

INDUSTRY

R&D Intelligence

COUNTDOWN hears Martin's *Pershing* has not met Army specs for low-temperature operation; a development program is under way to cure this problem. . . . Sylvania Electric expects to complete ground installations for the Army's *Advent* satellite next month at Fort Dix, N.J., and Camp Roberts, Calif. . . . At the Eglin Gulf Test Range, the Air Force is preparing to launch *Nike-Cajuns* to take IR measurements at 70 miles. . . . Marquardt has run a 25-lb.-thrust, radiation-cooled bipropellant (hydrazine and nitrogen tetroxide) pulse rocket continuously for 46 minutes.

Apollo's Management (Cont.)

NASA officials are letting it be known that they expect to have 300 persons on the *Apollo* management team in their Washington headquarters. Incidentally, this may come as a surprise, but NASA Administrator Webb says he has told President Kennedy that many people feel the *Apollo* program has been moving too *fast*.

Boosting Bomarc

With completion of the *Bomarc B* flight test program (35 shots), Boeing Co. is understood to be pushing a campaign to extend the *Bomarc* program—including a mobile model. Russia's unveiling of new jet bombers is salting the sales talk to NORAD.

Trend in Navy Drones?

Drone manufacturers are taking special note of a Navy decision to develop a Mach 2 tow target for use with the GE/Philco *Sidewinder* and Raytheon *Sparrow III*. The tows could be used with the McDonnell F4H and various Air Force Mach 2 interceptors.

The Price of SINS

The cost of Autonetics' SINS—ships inertial navigation systems—for *Polaris* nuclear-powered submarines is running at about $600,000 per ship. This figure includes stock components and shore systems. Each *Polaris* sub carries three SINS.

PERT, PERT, and More PERT

The Air Force is moving toward ever-greater use of the PERT system for keeping track of R&D programs and avoiding slippages. The Air Force Systems Command is understood to be looking for a number of new areas for using PERT in its many programs. At the same time, NASA also is embracing the Navy-developed management tool.

INTERNATIONAL

Still Sought: AA Missiles for Israel

The Israelis are continuing to press for permission from one NATO government or another to buy air defense missiles. The Israelis want to ring their principal cities with air defense missiles to defend themselves against a possible Arab surprise attack.

Germany to Top Blue Streak

The West Germans definitely will develop a third stage for the *Blue Streak* space booster. The previously reported decision has now been confirmed by the British Ministry of Aviation. The *Blue Streak* space booster will be used to orbit European communication satellites and various scientific payloads.

Overseas Pipeline

SBAC is tightening Britain's ties to the Continent by joining the Association International des Constructeurs de Materiel Aerospacial (AICMA). . . . Rumors continue in Western European capitals that the next Soviet *Vostok* probably will carry more than one cosmonaut. Some of the rumors even have a romantic touch—one of the space voyagers may be a cosmonautress. . . . The British Post Office will cooperate with the U.S. in testing communications satellites.

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The Missile/Space Week

Reds Step Nuclear Tests Into Multimegaton Class

The Soviets—presumably under simulated combat conditions—began exploding multimegaton nuclear warheads last week in their Barents and Kara sea maneuver area.

In addition, the Soviets said they would begin Sept. 13 launching "more powerful and improved rockets" capable of carrying 100-megaton warheads. The target area was designated as a region 185 by 200 miles some 375 miles south of Johnson Atoll in the Pacific. Test were to continue through Oct. 15.

The step up to multimegaton blasts occurred Sept. 10 in the sixth of the series of tests which began on Sept. 1 with kiloton yields. The Atomic Energy Commission reported that a seventh explosion on Sept. 12 was "on the order of several megatons." On Sept. 13, there were two more firings, both in the low-to-intermediate range.

Shots of the Week

NASA orbited a *Mercury-Atlas* carrying a robot astronaut Sept. 13. The capsule was recovered (see p. 91).

In a series of military firings, successes were mixed with failures.

• On the plus side, the Air Force successfully orbited *Discoverer XXX* Sept. 12 and planned to recover a capsule from the satellite in about four days time. A capsule was recovered Sept. 1 from *Discoverer XXIX*, which was orbited Aug. 30.

• A Martin *Titan* was fired on a successful 6000-mile flight from the Cape Sept. 6, in a test of its complete system—including the Mark IV reentry vehicle.

• On Sept. 9, the first full-scale test of a *Nike-Zeus* A-ICBM ended in an explosion shortly after second-stage ignition—and about 6 sec. after launch.

There was conjecture that the failure was caused by either a maneuver of the stage which exceeded design limits or an unprogrammed event which triggered the automatic destruct system. The test was to have ended on a command destruct, but Pacific Missile Range personnel at Point Mugu said the explosion was not initiated by them. A second *Zeus* test at PMR is expected before the end of the month.

• The *Zeus* launch was followed 25 min. later by the explosion of an *Atlas-Samos* on the pad at PMR's Point Arguello as it was being readied for firing. The Air Force was expected to attempt a backup launch of the picture-taking satellite shortly from an adjacent pad.

NIKE-ZEUS on pad at Pt. Mugu awaiting Sept. 9 launching.

• In a cooperative firing with French scientists Sept. 13, NASA loosed sodium vapor at altitudes of 120 and 228 miles to measure atmospheric winds, temperature and density. The launch with a four-stage rocket was from Wallops Island, Va.

Over Edwards AFB, Calif., Sept. 12, Test Pilot Joe Walker flew the *X-15* at about Mach 5 and to an altitude of about 100,000 ft.

New Strategy Fight

The controversial military strategy of "counterforce" backed by greatly expanded numbers of missiles again became an issue this week as the nation faced increasing Soviet aggressiveness.

A number of key congressmen on both sides of the aisle commented publicly and privately that the United States needed to switch from the defensive to the offensive in the Cold War.

At the same time, Gen. Thomas S. Power, commander of SAC, stated bluntly in a forthcoming book, "Combat Missileman":

"You've got to have a big stick today—a tremendous stick. You're dealing with gangsters. And gangsters don't do anything that there isn't any profit in. You deter through fear of consequences. Regardless of how a war starts, the enemy must know that we can destroy his military forces."

However, Administration critics have said repeatedly that the United States must not deploy sufficient missiles and other weapons to guarantee destruction of the Soviet forces under any circumstances.

This is the criticism that is behind much Capitol Hill grumbling about the need for taking the offensive.

Big Boosters Still Lead

Although NASA is taking a new look at rendezvous techniques as a possible method of beating the Russians to the moon, development of super-boosters still is the odds-on favorite.

New impetus was added to the long-discussed and long-neglected idea of an orbital station as a jump-off site for the lunar expedition in a National Press Club speech last week by Administrator James E. Webb.

Webb said NASA is analyzing the rendezvous capability of the *Saturn C-3* as an alternate approach to *Nova* for the manned lunar landing. He said this may affect the *C-3* configuration. But he made it clear that there is to be no slow-down in devel-

opment of big boosters.

The NASA official also disclosed that NASA is planning a 10-to-12-man orbital space station as a follow-on to the *Apollo* program. Decision whether to go ahead with this is expected by 1965.

Minuteman Case Contract

The Allison Div. of General Motors received a $10.935-million contract for first-stage *Minuteman* motor cases from Thiokol Chemical Corp. Deliveries under the production contract will begin this month and continue into the fall of 1962.

FABMIDS Studies In

The Army is sifting through 10-month feasibility studies on *FABMIDS* (Field Army Ballistic Missile Defense System).

Contractors participating were: The Raytheon Co., Northrop Corp., IBM, Pomona Div. of General Dynamics, Burroughs, Westinghouse, GE, Chrysler, Martin Co., Maxson Electronics Corp., Remington Rand's UNIVAC Div., and Sylvania Electronic Systems.

Other participants: Aeronutronic Div. of Ford, General Telephone and Electronics Corp., Hughes Aircraft, Goodyear Aircraft, North American Aircraft Co., LeTourneau Inc., and Aerojet-General.

Scientists Near Moon Pact

A proposal to internationalize the moon and planetary system neared agreement between Soviet and American scientists, meeting at Stowe, Vt.

The plan would call for establishing the same international status as exists for Antarctica.

The meeting, sponsored by the National Academy of Science and The American Academy of Arts and Sciences of Boston, is being attended by seven members of President Kennedy's Science Advisory Board and six members of the ruling body of the Soviet Academy of Science.

Another joint proposal likely to be approved by the conference calls for establishment of a joint Soviet-U.S. program in Space Biology.

New Team at Lockheed

Lockheed Aircraft Corp. management policies will remain unchanged under the new team which took office last week following the death of board chairman Robert E. Gross on Sept. 3.

Courtlandt S. Gross, company president for the past five years, succeeds his brother as chairman.

Daniel J. Haughton, executive vice president and former Georgia division manager, was named president.

Haughton, 50, joined Lockheed in 1939, became a vice president in 1952. He was named executive vice president and a corporation director in 1956 following his successful management of the Georgia division.

Dudley E. Brown, vice president-finance and a member of Lockheed top management for 20 years, was advanced to a group vice presidency.

LBJ to Address ARS Meeting

Vice President Lyndon B. Johnson will be the main speaker at the American Rocket Society's "Space Flight Report to the Nation" banquet at the Waldorf-Astoria in New York on Oct. 13.

Other scheduled speakers during the Oct. 9-15 convention include NASA Administrator James E. Webb and Gen. Bernard A. Schriever, chief of the Air Force Systems Command.

LTV, Thiokol Optimistic

Ling-Temco-Vought and Thiokol Chemical predict sharp rises in earnings for 1961.

LTV forecasts net earnings "substantially better" than the $1.25 reported for 1960 by predecessor Ling-Temco Electronics.

Thiokol predicts earnings of $1.20 per share and sales of $190 million, up from $171.5 million last year.

The company will begin production of *Minuteman* and *Pershing* motors late this year. They are looking for an Eastern U.S. site to develop Project *Nova* boosters. A prerequisite is access to deep water, so the large booster can be floated to Canaveral.

Strike Ends at Lowry

Union building craftsmen went back to work after a four-day strike at a *Titan* site at Lowry AFB, Colo., ending the first major missile-base walkout since the President set up the Missile Sites Labor Relations Committee.

The union decided to resume working pending Commission action on its dispute with the AMCO Fence Co. of Houston.

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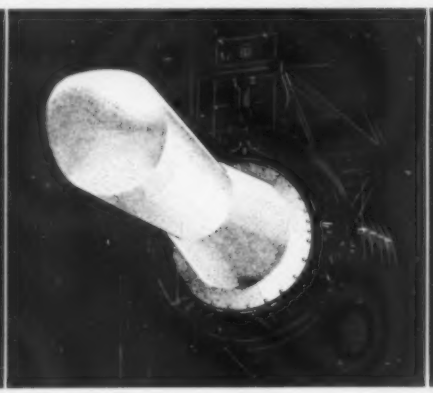
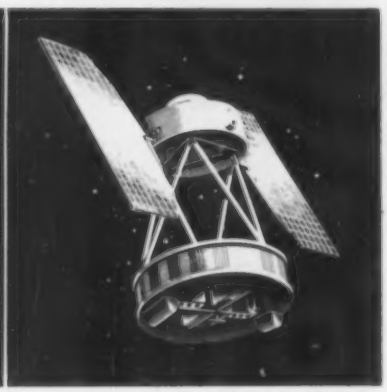
ENGINEERS

Solve Complex Problems in Support Systems for RE-ENTRY VEHICLES, SATELLITES, SPACE VEHICLES at the Missile & Space Vehicle Department

The Missile & Space Vehicle Department of General Electric—a recognized leader in the development of instrumented re-entry vehicles—is now pursuing a number of advanced space programs. Basic to progress in these programs is the solution of a diversity of interesting support problems. These include packaging, transportation, handling, mating, remote control, performance checkout and launch monitoring of the payload vehicle.

Future space programs will require even more advanced support systems with unique opportunities for men who can meet the challenges of this rapidly growing field of technology.





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Design and development of ground electronic systems, through the RF spectrum, for application in the support system of the re-entry or space vehicle. Requires BSEE, 6 years experience with background in such fields as communications, telemetry or radar.

ENGINEERS – GROUND & SPACE SUPPORT APPLICATION

To provide technical direction in the preliminary design involved in the development of ground and space support systems. BS plus 8 years experience with knowledge in electronics/electro-mechanical fields including monitor control and instrumentation system development.

DIGITAL COMPONENT DESIGN ENGINEERS

Design, development and evaluation of digital input/output devices for use in automatic checkout equipment. Requires EE with 3-5 years experience, including background in data processing input/output equipment or transistorized logic design.

ADVANCED ENGINEER MECHANICAL ELECTRO-MECHANICAL IMPLEMENTATION TECHNOLOGY

To advise and consult with mechanical and electro-mechanical design groups in incorporation of advanced implementation techniques in ground and space support components and systems. Requires minimum of MSME, 10 years experience with broad technical background.

ELECTRO-MECHANICAL ENGINEERS

Design and development of electro-mechanical components and systems for ground and space support systems. BSME with 6 years of experience including background in servo systems and electro-mechanical instrumentation.

CONTAINER & PACKAGE DEVELOPMENT ENGINEERS

Design and development of metal and non-metal reusable containers for shipping, storage and environmental control of large, fragile components and equipment. Requires BSME with container design, background and familiarity with military packaging specifications.

SYSTEMS ANALYSIS ENGINEERS

Design analysis of ground and space support equipment and systems. Requires EE or ME with experience in electronics/electro-mechanical field.

CRYOGENICS ENGINEER

Cryogenic design to include liquid oxygen, nitrogen and helium manufacturing storage or transfer systems, cryogenic cooling systems and heat exchanger design. Requires ME or Physics degree with 2-5 years experience.

LOGIC DESIGN ENGINEERS

Design and development of logic subassemblies for a large scale digital checkout system. Requires BSEE, 3-5 years experience and background in computer logic design emphasizing transistorized switching circuit techniques.

All qualified applicants will continue to receive consideration for employment without regard to race, creed, color or national origin.

▶ Apply by sending a brief resume of your experience to Mr. F. J. Wendt, Div. 486-WL, Missile & Space Vehicle Department, General Electric Company, 3198 Chestnut Street, Philadelphia 4, Pa.

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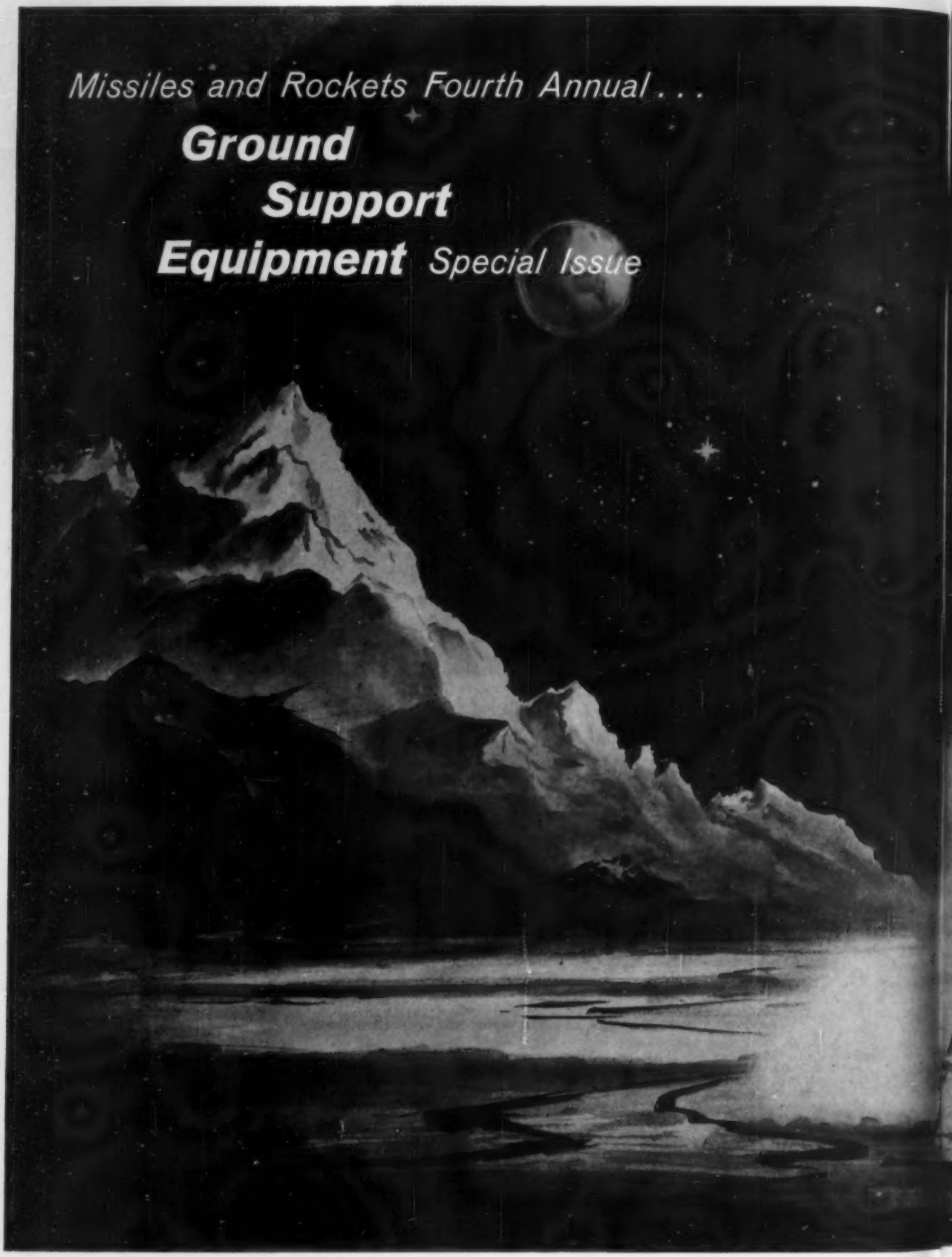
GENERAL ELECTRIC


Missiles and Rockets Fourth Annual . . .
Ground
Support
Equipment Special Issue

by James Trainor

GSE Headaches of the '60s

Man-to-Moon demands, changing missile picture carve support industry into brand-new pattern

HARSH NEW challenges are reshaping the great, amorphous support equipment industry into two sharply distinct forms.

Until now, the lines for support of missile and space systems have frequently crossed. However, with the decision to race Russia to the moon, the paths are separating. From now on there will be GSE tailored expressly for missiles and GSE tailored expressly for space.

On one hand, the vast U.S. lunar program is posing a demand for the development of ground systems unprecedented in size and complexity.

On the other hand, industry is confronted by the resumption of nuclear testing, which is expected to bring into being whole new families of small, highly mobile missiles. Thus, the essential difference comes down to one of size.

There now seems to be almost universal acceptance of the inalterable fact that GSE is as important as the missile or space vehicle it is to support—and, hence, design and development of GSE must be concurrent. NASA Administrator James E. Webb underscored this point last week, declaring that facilities are the "pacing item" in the *Apollo* lunar program, rather than the boosters or spacecraft.

These are but some of the prevailing currents apparent in the survey of selected missile and space GSE areas in the following pages.

(Continued on next page)

How will the big and little problems be solved to insure the success of missile and space programs? Here's the way some experts see the future shaping up:

In the space program, the enormous height and girth of the *Nova* and *Saturn* boosters create GSE demands for which there is little experience. While among the more sophisticated lunar and planetary instrumented probes—like *Prospector* and *Mariner*—there is a requirement for more specialized GSE, particularly checkout and simulation equipment, to enable them to meet a narrow firing window.

Perhaps the only area of support equipment that is not a matter of serious concern is the fueling equipment. The consensus seems to be that larger pumps, greater launch-site cryogenic storage facilities and increased propellant manufacture at Cape Canaveral will be sufficient to meet the support requirements of *Saturn,* or even *Nova,* launchings.

However, this optimism does not extend to nuclear rockets.

The gantry—long an essential piece of GSE—is undergoing serious reappraisal. In fact, for the *Saturn C-3* which is expected to have a relatively high rate of fire, it is to be eliminated and replaced by a simple umbilical-servicing mast.

For *Nova,* the massive service structure may prove to be too heavy to move and so the space vehicle may be fired through it or the structure may be folded back like a giant clamshell.

Checkout procedures are also undergoing re-evaluation. The problem: to checkout the myriad of components on a *Nova* vehicle in approximately one-sixth the time required to check a standard *Redstone.* The hoped-for solution: greater reliance on automatic, high-speed data processing equipment, increased use of digital links to the blockhouse and integration of telemetry packages into the checkout procedures.

Azimuth alignment of these large spacecraft is also a challenge. The sway for a vehicle of the *Nova's* size may require tracking equipment for the alignment theodolite. Atmospheric effects and distance from the target also pose problems for the alignment devices.

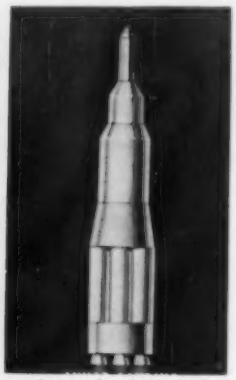
There are, of course, many other problems and challenges in spacecraft GSE. However, none is more critical than lunar GSE. For, in effect, one authority has stipulated a requirement for the *Apollo* spacecraft that every component and every system have a *known* lifetime to insure its functioning throughout the entire lunar landing and takeoff mission.

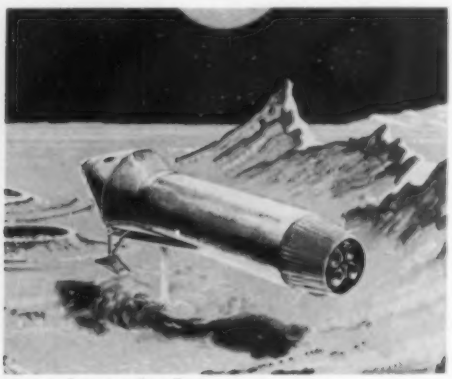
These then are some of the challenges facing the designers of support equipment for space systems. However, this is only one side of the coin. Equally challenging problems face designers of missile support equipment.

Hardening of missile sites—once considered a closed issue—may have to be re-evaluated in light of the Soviet threat to build a 100 megaton bomb. Such a second look would probably place added support requirements on the hardened systems. Greater resistance to overpressures will also have to be considered for the command and control centers which the Administration considers such an essential part of our defense posture.

The greater emphasis in the Defense Department on getting more defense per dollar has given new life to reliability and value analysis programs in industry. The majority of the firms queried by M/R said that reducing the cost of GSE across the board and insuring longer life and lower component failure rates were primary considerations in their planning.

Mobility—long a preserve of the Army—is getting increased Air Force attention. The problems of *Skybolt*—the B-52, air-launched ballistic missile—center around the age-old difficulties of determining accurately a particular location on the earth's surface. At supersonic speeds, this problem of navigation becomes even more acute.





SIZE OF THE PROBLEM . . . *in warheads . . . boosters . . . lunar takeoff*

Lightweight, mobile systems—capable of surviving in any environment—are still unachieved goals of the Army. However, reaction time and "wooden round" checkout are also areas of immediate concern. The tendency for an Army system—particularly its GSE—to become heavier as it moves through the development cycle is a trend which the Army is still trying to reverse.

These then are some of the challenges that must be faced if effective support equipment for this country's missile and space programs is to be developed. It is not a complete list, but it is representative of the areas of concern to the Defense Department, NASA and industry.

The very fact that, during the next five years, GSE will consume 30-50% of the total systems cost has accented the concern felt by many that GSE can no longer be neglected or treated as a step-child. And this realization—even in the face of the problems to be solved—is the most encouraging aspect of the 1961 Ground Support Equipment picture. ⌗

Events Forcing Big Surge in Spending

Commitment to moon race, bolstering of missile arsenal, demand for extra hardening of ICBM sites likely to push support costs far beyond current $4-6 billion a year

by James Baar

A TRIPLE WALLOP—the new U.S. drive to the moon, the Berlin crisis and the resumption of nuclear testing—is expected to force the currently large demand for ground support equipment to rise steeply over the next 18 months.

The new demand will more than wipe out the slump in the ground equipment market previously forecast because of the "buy out" of the big *Atlas* and *Titan* ICBM systems.

The GSE market—or, in the latest Air Force terminology, the AGE (aerospace-ground equipment) market—is as difficult as ever to tag with a price because of the wide variations in what different Defense Department and NASA budgets include. However, depending on what is included, this market is running from about $4 billion to $6 billion annually, and is rising.

The key areas where this rise is occurring are:

- **The space program**—A nearly $1-billion expansion program at Cape Canaveral alone is getting under way. Meantime, more test, tracking and launch facilities are expected to be built at other U.S. ranges and industrial sites and at stations around the earth. And the requirements for a wide variety of new space support equipment are just being written.
- **The missile program**—Procurement of tactical systems is already increasing and is expected to increase considerably more in the FY '63 defense budget. Also, one or more new strategic missile systems with special GSE requirements are expected to be started.
- **The hardened sites program**—The development of huge nuclear warheads by Russia is expected to force greater hardening of missile sites, command and control centers and communication systems.

The magnitude of the cost of the ground support equipment for the space program is clearly indicated in the plans announced to date for Cape Canaveral.

At present, six new launching complexes for superboosters are planned by NASA. The estimated cost of building and equipping them, along with industrial and cryogenic facilities, is about $800 million. That means the launching pads including all auxiliary facilities will cost about $130 million each.

By way of comparison, the appropriations for construction of facilities for the *Saturn* booster program through FY '62 total $86.2 million; the cost of building and equipping a 12-missile *Atlas* squadron is about $152 million.

The expansion at the Cape is clearly only the beginning of the investment in support equipment in the drive to the moon. Some estimates put the annual expenditure by NASA for procurement and R&D of support equipment and facilities at well over $1 billion by FY '64.

In the missile program, the full effect of the Berlin military buildup on procurement is yet to be felt.

For the first time, the Army is expected to receive authority for large scale procurement of new tactical missile systems. Such new missiles as the Martin *Pershing* and Sperry *Sergeant* involve large quantities of support equipment.

Moreover, the Berlin crisis and new Soviet nuclear tests are putting new pressure behind Army arguments for the deployment of the *Nike-Zeus* antimissile missile. The cost of deployment and production of *Zeus* is estimated conservatively at about $7.5 billion, much of it GSE.

The proof-of-the-pudding tests for the big Western Electric missile are scheduled for early next year in the mid-Pacific. The chances of a decision to begin production next year are now considered to be good.

The Navy also is expanding its procurement of tactical missiles and the addition of considerably more missile warships with their large quantities of support equipment is expected.

Whether the Navy will build more *Polaris* submarines beyond the 29 currently authorized has yet to be decided. However, pressure from Congress seems to make an increase in the fleet to at least 39 to 45 inevitable.

The latest-class *Polaris* submarines are costing $116.2 million each. About $39 million of this is support equipment.

In the field of R&D, highly mobile strategic missiles are expected to be made increasingly attractive by the improvements in nuclear warheads which U.S. physicists anticipate will result from renewed nuclear testing.

These missiles probably will be deployed on some form of truck or spacecraft. Very new ground and space support equipment will necessarily have to be developed for such systems.

Also, new support is expected for resuming the rapid development of the train-launched *Minuteman* ICBM. Some estimates of the cost of support equipment for the deployment of a force of 200 mobile *Minutemen* run about $1 billion.

Probably it is in the U.S. hardened sites programs that the announced Soviet plan to develop 100-megation nuclear warheads will have one of the most profound effects.

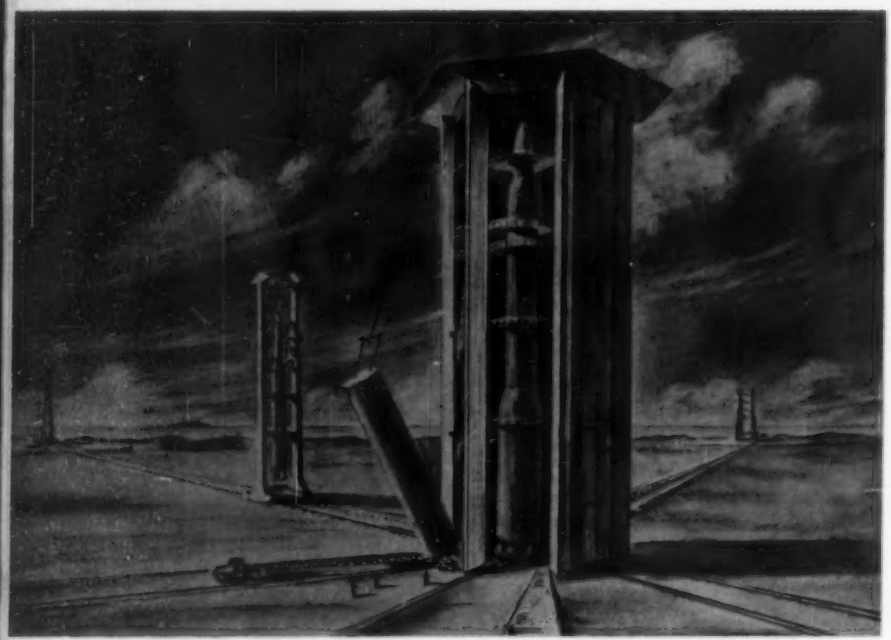
Air Force plans call for hardening fixed *Minuteman* sites to about 200 psi. These plans were formulated on the basis that the Russians would attack the sites with warheads in the 10 megaton class.

By using 100-megaton warheads, the Soviets could significantly decrease the number of missiles needed to have a high probability of knocking out the fixed *Minuteman* force. Therefore, to maintain the same survivability ratio the sites would have to be made much harder—possibly to 500 or 1000 psi or more. Such a move would cause costs to increase considerably.

The GSE market is in a state of great change and adjustment to new developments. Almost all changes and adjustments point toward expansion. ⠿

Apollo: Giant Equipment, Problems

Manned space-flight effort introduces entirely new parameters in transportation, assembly and checkout



SPACE VEHICLES of Saturn C-3 class will be assembled, checked out and serviced in huge structures like the one shown, then will move by rail-canal system to the launch pad

ALTHOUGH STILL to be finalized, the picture that is emerging of the equipment required to support NASA's manned space flight program staggers the imagination. In sheer size and complexity, this space GSE outstrips anything that has been done in this country's missile and space programs to date.

For example, the gantry for the *Nova* vehicle will be so massive that it most likely cannot be moved away from the missile before firing. This unique limitation has forced NASA to talk about firing the huge *Nova* vehicle through the gantry or hinging the servicing structure so that it can be folded back like a clam-shell before liftoff. Which approach will finally be selected has not as yet been decided. However, this is illustrative of the unique problems of GSE for the *Apollo* program.

• **Which way to the pad?**—One of the first considerations facing GSE designers is the simple question of how do you transport the out-size boosters, upper stages and the *Apollo* spacecraft to the launch site? Everything from on-site manufacture and assembly to lighter-than-air craft has been proposed.

The most likely method—and the only one being seriously considered by NASA—is the tried and true barge transport system used with *Saturn*. Using this system, according to NASA, the only new requirement will be for larger and larger barges to handle the *Saturn C-3* and the *Nova*.

The determining factor, however, will be the decision on whether direct or orbital rendezvous flight will be used for the lunar landing. (NASA officials concede that direct flight is the odds-on favorite.) The goal of either approach, however, is to achieve the shortest possible shipping time.

Therefore, in addition to the barge system, studies are being conducted to determine whether a modified C-133 aircraft might be used or perhaps an

entirely new aircraft developed. Running a poor third in the transportation race is the lighter-than-air proposal.

The *Apollo* spacecraft itself will have to live in a protected environment from the time it leaves the factory until it is launched. Even after being placed on the missile, the craft will be shrouded to protect it from corrosion and to provide it with conditioned air.

• **Assembly: Saturn C-3**—Once all of the components reach Cape Canaveral the *C-3* will be assembled and checked out vertically well away from the launch pad. The assembly and checkout building—the most accurate and up-to-date illustration of which accompanies this article—will also be a unique structure. With a ceiling over 400 ft. from the ground, it will provide many of the functions previously handled by the gantry. Assembly, checkout and servicing—all conducted in this facility—eliminate the need for anything but a simple umbilical-servicing mast at the launch site.

Once checked out and ready for firing, the *C-3*—still in the vertical—will be transported from the building to launch pad by a combination canal-rail system. The vehicle moves on a specially designed "trolley car."

The main advantage of the rail-canal system—rather than a straight rail approach—is that the canal enables the vehicle to be more easily positioned and also eases the possibility of rail deformation.

Although the vertical assembly and checkout approach costs more initially for the construction of facilities, it has two main advantages over the more conventional procedures: It gives a higher rate of fire capability in that launch pads are not tied up with one vehicle for long periods of time and it eases the vehicle design problems by simplifying the requirements for lifting points. Also, the vehicle can be pulled back into a completely protected area in approximately two hours.

• **Assembly: Nova**—The tremendous size of the *Nova* precludes any use of a system such as that described above. This vehicle will necessarily be assembled and checked out on its launch pad. However, due to the lower rates of fire contemplated for *Nova*, this does not impose a penalty on the use of the launch facilities.

The gantry—weighing some 3500-4000 tons—will be completely enclosed and will stand approximately 435 feet high and be 120 feet wide at the base. Semimonocoque constructed, the twin towers would be topped by a head which supports a mobile crane for flight vehicle assembly, checkout and transport. The towers would contain work areas for most of the checkout and servicing gear required up to the time the vehicle is placed on the launch pad and the umbilical tower connected.

In this connection, studies are being conducted by NASA to determine the gantry requirements for both liquid and solid propellant boosters. It is essential that the differences between the two be delineated, as one NASA official put it, because the country cannot afford to build separate facilities for each.

The umbilical tower for last-minute servicing of the vehicle could consist of a standard-type crane above a fixed tower. The crane boom would be used to lean into the vehicle's upper stages with access to the vehicle by means of adjustable access platforms. The tower would also contain an elevator to lift the flight crew to the *Apollo* command capsule during the countdown.

• **Computers and countdowns**—Once a vehicle is on the launch pad, the main consideration will be to launch it as soon as possible. The long, tedious countdowns of the past will be eliminated by a greater reliance on automatic data processing equipment. However, NASA is not ready to rely completely on computer checkout, rather it is aiming at an optimum man-machine relationship to provide rapid, fail-safe checkout.

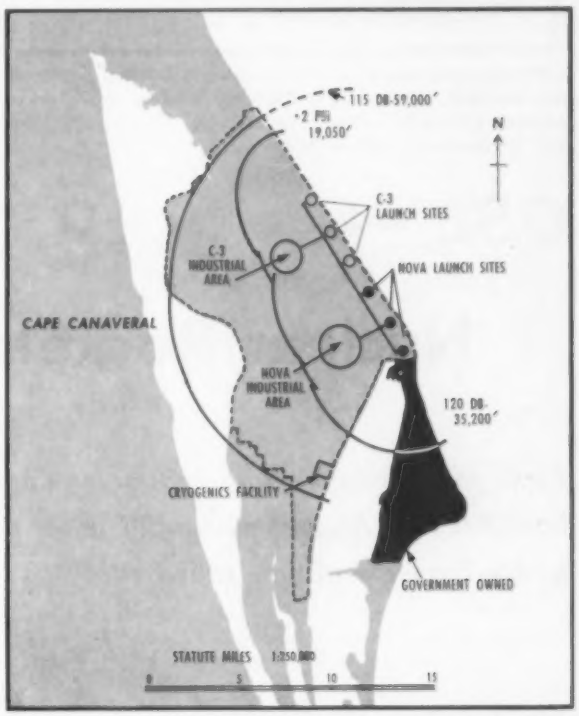
Whatever the final breakdown, however, the checkout system will have to provide a high degree of truthfulness in addition to cataloguing statistical data on the myriad of components in the *Nova* and *C-3* vehicles.

The fundamental difference between the large space vehicle and its more parochial cousins will be the integration of digital and telemetry-package outputs into the checkout procedures. Since the blockhouses for both the *Nova* and the *C-3* are expected to be located at some distance from the launch pad, the use of digital data rather than analog will eliminate the problems inherent in long distance transmission of the analog data.

However, the digital approach will necessitate a series of conversions from analog signals in the missile to digital and perhaps back to analog at the blockhouse. The use of telemetry packages for checkout seems to spring from the attitude that the equipment is there anyway and it can do the job so why not use it and save both time and equipment.

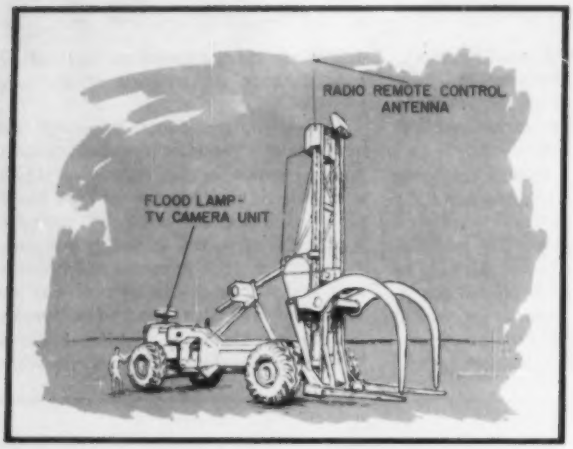
Perhaps the only problem concerning support equipment for space which doesn't have designers worried is fueling. There is a consensus among those most concerned with the lunar program that the fueling problem will entail little more than larger pumps and higher pumping rates.

In addition, they feel that a high-output cryogenics facility will have to be built at Canaveral to support the space launches. The liquid oxygen, hydrogen and nitrogen would be manufactured at this facility and truck-transported to large storage tanks at the launch site. With the high firing rates predicted by NASA for the *C-3*, this belies the need for a facility producing many tons a day of the highly volatile

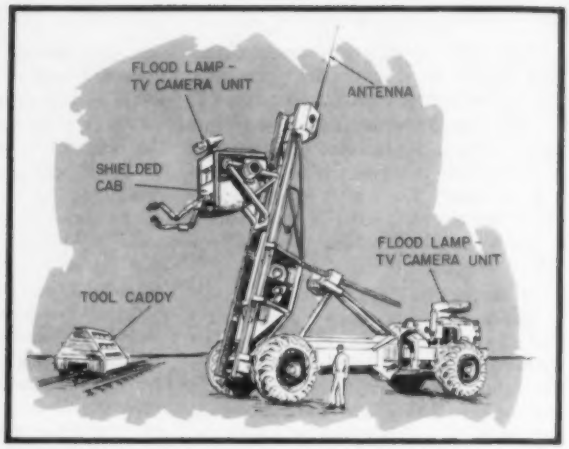


MAP of space vehicle launch complex. Note that the industrial complex will be located well within the 120-db line—a noise level that could cause structural problems.

(Continued on page 68)



FORKMAN. *Large engine sections could be handled easily with this modified fork lift truck. AMF has no firm idea as to the number of types of remote vehicles needed at a launch or test site. Its pessimistic attitude is evident.*



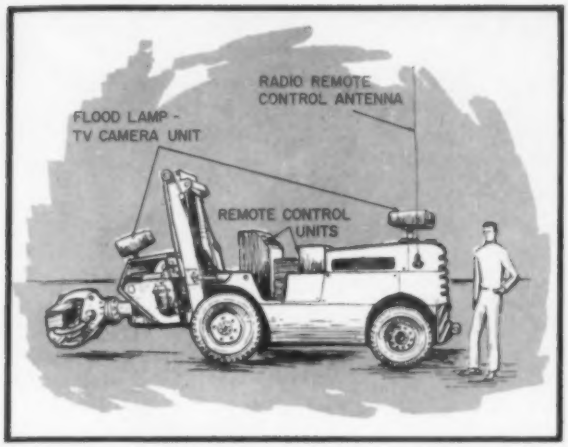
HANDYMAN AND TOOL CADDY. *Off-road capability is combined with the shielded cab concept to bring a man as close to the work as possible. The basic vehicle is very similar to conventional heavy construction units currently in use.*

GSE SPACE

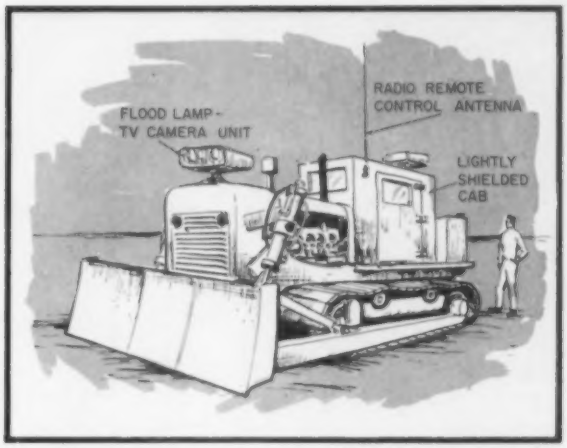
Nuclear Rocketry Hopes Hobbled by L

Years of experience with reactor equipment have left AMF Atomics pessimistic about prospects—longer lead time called vital

MODELS ILLUSTRATE the versatility of mobile manned shielded cab. Unit at right could be used to separate engine components in the MAD building.



CLAWMAN. *Heavy-duty capability in lifting and positioning radioactive sections too large or bulky for smaller handling units is afforded by this mobile vehicle. Like all the remote equipment, the unit can be manually operated.*



SANDMAN. *One of the all-purpose vehicles maintained in case of an accident. Bulldozer could shove radioactive rubble to a safe site, or possibly bury it until it was "cold" enough to permit manned inspection and recovery.*

Limitations of Remote Handling

By John F. Judge

GREENWICH, CONN.—Unless there is a complete reversal of the conventional ground support equipment approach, some experts fear the nuclear engine could easily be designed right out of the U.S. rocket program.

The key problem: remote handling.

The engine must be designed from the start for remote assembly, inspection and checkout—something brand new in rocket technology. If this is not done, then the cost of the program as the launch date approaches will be prohibitive.

Removing man from such an operation raises a host of problems. AMF Atomics, a firm long skilled in reactor technology, is attempting to reverse the process. Years of designing and building remote-handling equipment for reactors has brought home the fact that no mechanical means can really replace a man's hands.

• **Belly up to work**—The basic note of the AMF nuclear support approach is to get the man as close to the work as possible. Even then there will be a need for remote operations. Thus, if an engine is not designed with this in mind it becomes a one-shot affair, incapable of check-out corrections.

H. C. Neale, Engineering Manager, says the engineering aspects of Nuclear Support Equipment (NSE) are grounded in current nuclear technology but advanced engine concepts will require NSE beyond the present state of the art in machine development.

Neale and his associates have found that the more complex a remote handling operation becomes, the less efficient it is in comparison with a man. "There are innumerable little things in the simple turning of a nut that crop up in attempting to mechanize the job," he says. Not the least of which is visibility.

This leads to one of the commandments in remote operations—if it cannot be seen, it cannot be done. And TV is a miserable substitute for the eye.

• **Nuclear background**—AMF Atomics is a world leader in the research reactor field. In 1942 the firm got its feet wet machining uranium for the legendary Manhattan Project. Special components were built for Hanford and Oak Ridge and the responsibility for all the machinery and handling equipment at the Savannah River heavy-water production reactor lay with the firm. Most of this equipment is still at work more than 10 years later.

The long association with things nuclear has given AMF more than a manufacturing capability—it created an atmosphere of pessimism. NSE people at AMF are firm adherents of "Murphy's Law." They are convinced that if anything can go wrong, it will—and at the least desirable time.

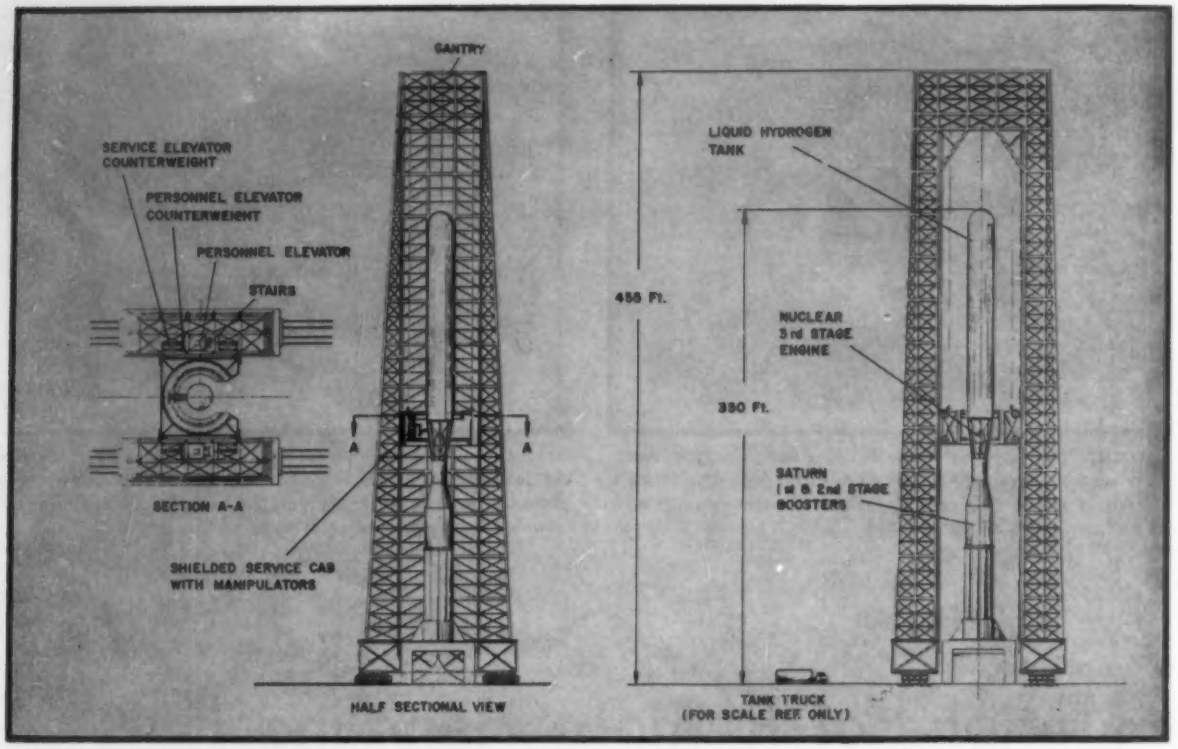
This philosophy is most apparent in their NSE plans. One avenue is never enough, there must three or more for every minute segment of the job. They expect the worst and design for it.

The firm has active plans for a motor assembly and disassembly (MAD) building capable of handling current and future generations of nuclear engines. The facility is designed to handle the entire engine, break it down into major components and hustle each of these off into small hot rooms for detailed remote work.

The building is connected with various test stands by a remotely operated railway. Each handling structure is designed to expand with the different requirements of an active engine program, and all can cluster for a task.

Launch NSE is somewhat more complex. AMF spokesman say that the engines will eventually have to be assembled at the pad. This involves some fairly large and complex facilities.

Mobile handling equipment will be a necessity. Neale says the vehicles themselves pose no major problems. Most of them are familiar sights on heavy construction projects. It's the



AMF INCLUDES a shielded service cab in the gantry complex for a nuclear-staged rocket. The cab would have direct vision and television capabilities, together with remote manipulators. Direct observation is strongly preferred.

addition of the remote handling apparatus that is tricky.

One AMF concept in this area that drew wide interest is a general-purpose, manned, shielded vehicle. Completely mobile, the unit can handle a host of functions at test areas and on the launching pad itself. Again, it brings the man right up to the work.

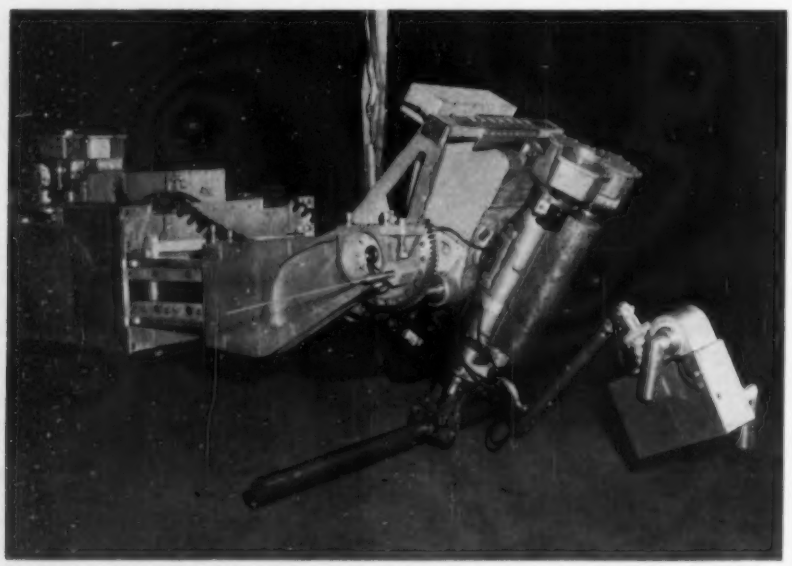
AMF spokesmen expect the realities of nuclear engines as part of space missions will involve many things currently unforeseeable. The most difficult aspect of their job is simply that the engines do not exist. Plans must be predicated on projected needs—requirements that will change and often.

• **Guessable inputs**—The engines are so expensive that recovery methods will probably be perfected; NSE projections must take this into account. An operational rocket with a nuclear upper stage will probably have some means of ascertaining the reactor's readiness during the final countdown. This might involve running it at some low percentage of its total power. Instrument limitations currently peg this at about 0.5% power. Another factor in NSE projections becomes evident.

Applying Murphy's Law to launch operations leads to the inclusion of another capacity in ground operations. A "disaster" crew with proper equipment will also be needed. Such a unit would have the training and means to handle every conceivable type of mishap on the pad and after launch.

Nuclear support does not end with launch. There will be a demand for space-platform remote handling, testing and inspection. Nuclear engines will give the U.S. a lunar landing capability, thus extending the NSE requirements to the moon. Exploration sites will use nuclear power and wherever a reactor goes, so does a certain amount of remote handling equipment.

AMF is sure of one point—engines are not the only long-lead item in a nuclear rocket program. ⌘



THIS REMOTE HANDLING DEVICE has been in service at the Savannah River reactor for more than 10 years. As one AMF engineer cracked, "It's not streamlined because it doesn't move fast." The unit illustrates the complexities of a manipulator.

Refining Azimuth Heading Accuracy

Optical alignment systems are being made more and more sophisticated for seconds-of-arc demands of future moon firings

by George Mrus*

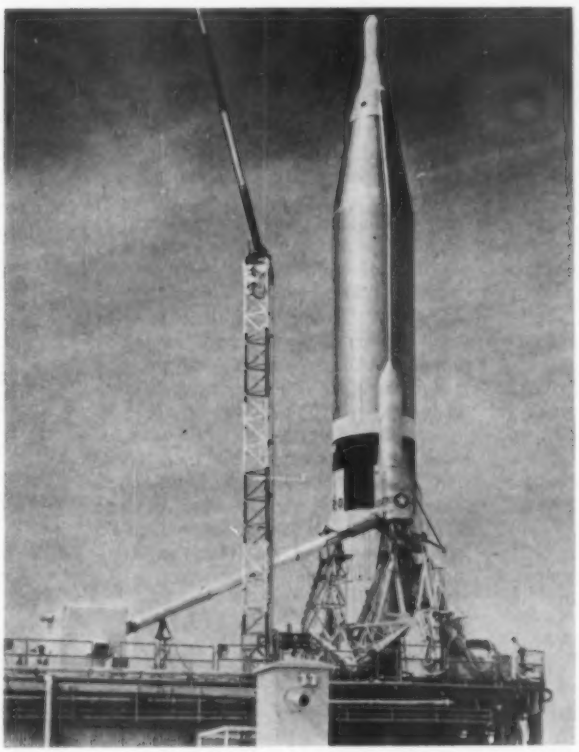
PERHAPS the most critical element in accurately aligning space vehicles to shoot the moon is correct azimuth heading.

Aiming a space vehicle involves seconds-of-arc pointing accuracy—far greater than that required for missiles traveling short distances. And new electro-optical alignment instruments have been developed to meet this increased accuracy requirement.

The inertial guidance system depends upon having the three axes space-stabilized prior to launch, fortunately gravity automatically provides the capability of aligning the two horizontal axes with equipment built into the alignment platform.

However, there is no simple automatic heading device. Azimuth alignment must be performed with a reference external to the missile—one being *Polaris*. Sights can be taken on *Polaris* at the time of alignment, or bench marks previously located from *Polaris* can provide references from which the true azimuth heading can be determined prior to launch.

Another method of providing a correct azimuth heading reference is through the use of the North-Seeking Gyro, which is rapidly increasing in accuracy. Both of these methods supply only bench marks and require a device to transfer the reference from the bench marks to the platform.



ATLAS ON LAUNCH PAD with azimuth alignment equipment developed by Arma to overcome early problem of "shimmer."

Gyro-Compassing methods are being investigated with considerable optimism. This technique is a mode of operation of the inertial system itself which requires no external azimuth reference transfer. However, in its present state of development Gyro-Compassing manifests many problems; it will be some time before inertial guidance systems employ it for azimuth alignment.

Today, optical alignment systems are becoming extremely sophisticated. The importance of missile alignment in the future will also be very great. The pointing errors are quite significant when terrestrial distances are long.

A 20-second azimuth error in a 1500-mile flight would give an equivalent 0.15-mile target error, and when discussing celestial distances the errors become astronomical. For instance, the moon is approximately 248,000 miles from the earth; a 20-second error at this distance would result in a 25-mile error at the moon's surface.

• **Large vehicle problems**—Current plans for launching large space probes at Cape Canaveral present special alignment problems to the electro-optical engineer. Standing on their bases, subject to the atmosphere and various perturbations, the unprotected large space vehicles particularly complicate the problems associated with the transfer of the azimuth heading.

The alignment geometry associated with the large space probes is shown in the illustration on page 24. The vehicle, as shown, rests with its base on the launch pad at ground level and with the inertial system located in the uppermost stage. The theodolite—installed on a base near ground level—projects a beam of collimated light at the correct angle to the reflecting prism mounted on the stable platform in the missile.

To achieve the greatest accuracy in azimuth transfer, the theodolite should ideally be located at the same height as the platform prism, since azimuth accuracy decreases as the sight elevation increases. However, the sheer size of the space probes renders this impractical.

Therefore, a compromise between the distance from the vehicle and sight

*Mr. Mrus is with the Electro-Optical Division of the Perkin-Elmer Corp.

Atmosphere makes most trouble . . .

angle is necessary. Since the explosive hazard also dictates that the theodolite be located some distance away, a 30 degree angle was chosen as the best compromise.

To illustrate the magnitude of the problem, a 200-ft. *Saturn* vehicle would have an estimated sway of anywhere up to ± 10 feet and the theodolite—located 350 feet from the base of the missile—would have a slant range line of sight of 400 feet. Comparable statistics for a 300-400 ft. *Nova* vehicle read like this: sway—unknown, distance of theodolite from base of the missile—500 to 700 feet giving a slant range of 600 to 800 feet.

• **Alignment geometry**—It is important to appreciate that the basic geometrical facts of optical alignment are necessary to the operation of inertial platform alignment. The present state of development of alignment instrumentation must now contend with the new problems fostered by the large space probes.

Alignment instrumentation must conform to the requirements of the vehicle and inertial system designers. For example, the more sophisticated inertial systems have an attendant decrease in physical size which limits the size of the reflecting prism. An early system used a 6 in. x 3 in. reflector prism at distances up to 1000 feet. Today, the reflectors on some platforms are smaller than 1 in. x 1 in. with the requirement for monitoring at fairly long ranges.

As long as the alignment theodolite is located a short distance from this small reflector, many of the alignment problems are eliminated. However, as discussed previously, this is not always possible or desirable.

• **Atmospheric problems**—More fundamental alignment problems, however, are those of the atmosphere. Atmospheric perturbations can affect both the alignment accuracy and the theodolite ability to supply an azimuth reference to the vehicle platform. Several of the more important problems in this area are:

—"Seeing" the prism due to problems attributable to light attentuation and forward scattering.

—Back-scattering resulting from haze and fog which not only attenuates the light but can prevent azimuth reference transfer by raising the noise level at the theodolite.

—Finally and most important, "shimmer" or atmospheric boil.

Shimmer is due to the thermocurrents of radiance which are generated by energy from the sun causing the density of the atmosphere to vary. The shimmer problem — most pronounced on a sunny day when the optical line of sight passes close to air, earth, sand and pavement—can be minimized by aligning the missile at night when the ground radiance is lowest or mounting the theodolite above the ground to place it above the maximum turbulent areas of the atmosphere.

Another interesting technique for reducing effects of air turbulence was that used by the Arma Division of American Bosch Arma Corp. at Cape Canaveral. Arma used a double-walled light beam tunnel between the alignment theodolite and the reflector in the *Atlas* ICBM.

By air-conditioning the area between the inner and outer tube, a uniform temperature gradient was achieved in the inner tube and prevented thermal currents from disturbing the line of sight. Since the reflector is located near the base of the missile and only required a tunnel about 50 ft. long, this system worked well.

Since shimmer causes the reflected collimated light beam to oscillate back and forth more or less equally, it decreases the instrument accuracy and causes the noise level of the theodolite to increase. The average direction of the beam, however, still correctly represents the line of sight—hence the azimuth heading.

• **Space probe alignment**—Assuming that all the atmospheric conditions have been minimized or compensated for, a correct azimuth line-of-sight still must be established by the alignment theodolite. The theodolite projects a beam of collimated light to the vehicle reference prism. The vehicle must be aligned so that the reflector is located in the collimated beam of light. In addition, the reflector must send light back into the theodolite.

In the case of the new space probes —basically very tall, extremely slender, thin-wall tubes—the alignment problem is very difficult. If these vehicles were strictly thin-wall tubes, the various motions that could take place would be predictable. Unfortunately, this is not so. An unsheltered, erected vehicle exposed to the sun will bend away from the sun. In addition, a twist or torsion of the entire vehicle occurs. Added to this is the vehicle sway caused by the wind, which can only be estimated.

The large space probes create addi-

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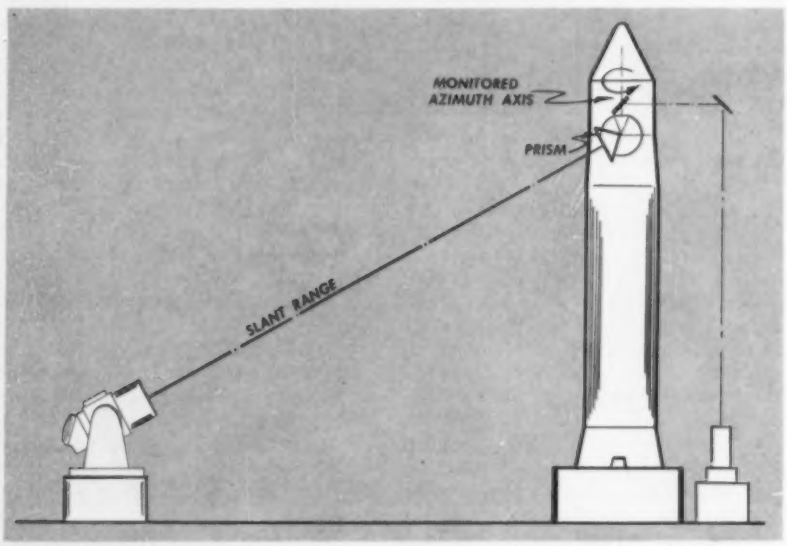
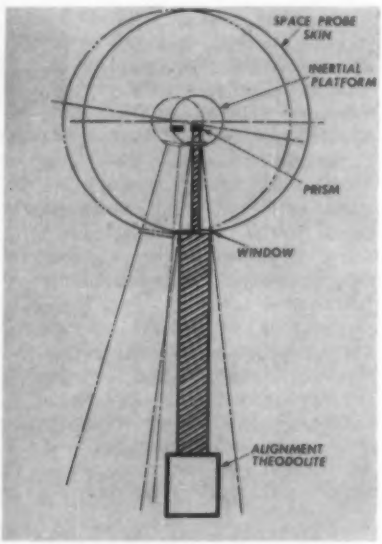
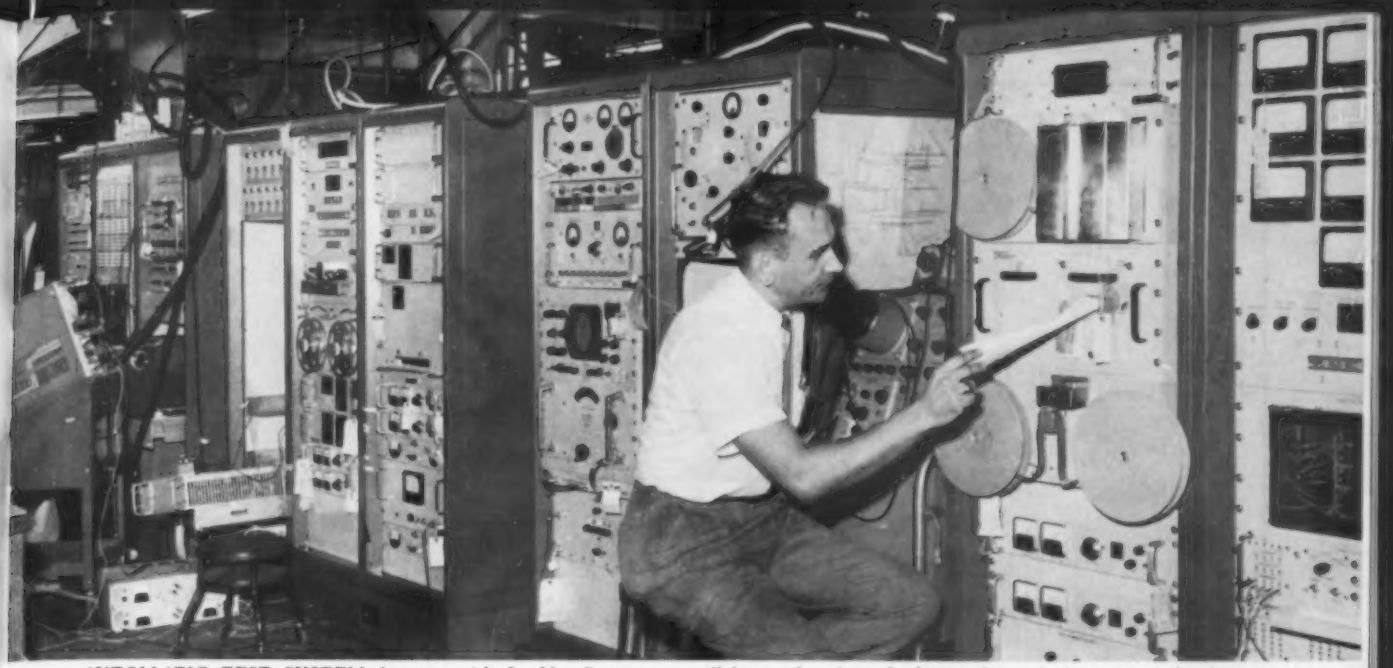


PRISM MUST be acquired on inertial platform at slant range up to 800 feet.



SWAY could fully vignette prism.



AUTOMATIC TEST SYSTEM for use with Lockheed's new high-vacuum orbital simulator undergoes final checkout before it is installed. Developed by RCA, the system (called APATS) will be employed to check out electronic instruments for future space vehicles in a realistic environment.

GSE SPACE

'APATS' To Speed Environment Testing

by David B. Dobson

Defense Electronics Product Div.
Radio Corporation of America

A NEW CHECKOUT system which eliminates the need for specialized test equipment will soon be employed for realistic testing of electronic packages in a space environment.

Built by Radio Corporation of America in Camden, N.J., it will be used with a high-vacuum orbital simulator now being installed at Lockheed Missiles & Space Co. in Sunnyvale, Calif.

The rapidly growing number of space missions and types of vehicles, and their accompanying requirements for a multitude of highly complex test instrumentations, have generated a need for a reliable and accurate specimen evaluator.

Testing space vehicle electronic equipment under simulated environmental conditions is a complicated and time-consuming procedure. This is truer than ever today, when tests are still being performed manually and the results recorded by hand. This imposes an intolerable demand for more time and consequently delays the test program.

Each vehicle tested under current procedures requires the use of specialized test apparatus in conjunction with the test chamber and its associated equipment. This means that several technicians are needed to perform the test and to calibrate the equipment, which dictates an increase in setup and test time.

Also, the use of specialized test equipment tends to produce many test equipment malfunctions, which further delay environmental testing of complex electronic specimens.

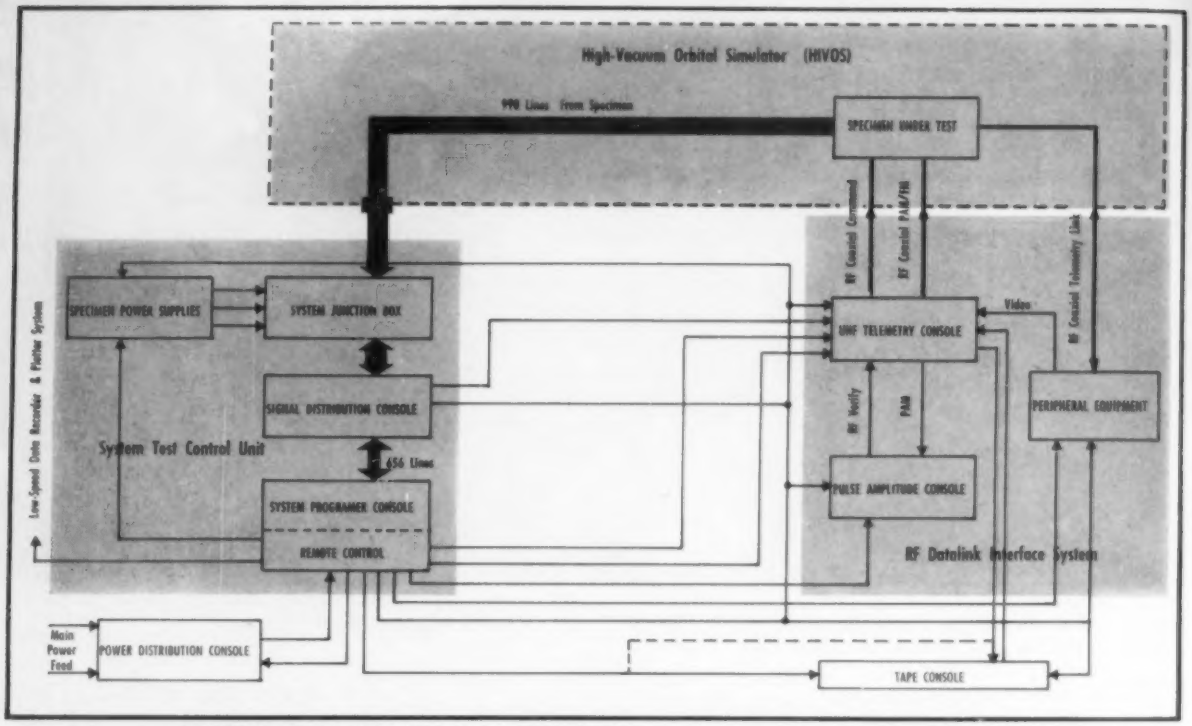
• **APATS joins HIVOS**—To provide the capability of testing and evaluating spacecraft specimens automatically, RCA designed and built the automatic programer and test system (APATS) for use with the Lockheed high-vacuum orbital simulator (HIVOS). This simulator is now being erected.

Mounted in 12 racks and using standardized functional modules, APATS provides an easily maintained and expanded instrumentation system, its developers believe. Although requirements for the marriage of HIVOS and APATS were extremely complex, the test system was completed and ready for installation within 9 months.

APATS design eliminates the need for special-purpose test equipments, since it is an integrated, general-purpose, automatic system capable of performing a multitude of tests for all specimens to be evaluated in the simulator. Because test equipment calibration, maintenance, and operation are automated, the number of operating personnel can be kept to a minimum.

The system employs RCA solid-state circuit designs previously proven extremely reliable and efficient in Army Signal Corps systems. Circuits which make up the digital control logic elements—such as gates, registers, counters, power amplifiers, relay drivers, comparators, program controllers and tape controls—all have proven records of operational reliability.

• **System description** — APATS automatically performs preprogramed tests on vehicle and satellite specimens while they are contained in the simula-



OVERALL BLOCK DIAGRAM OF APATS (Automatic Programing and Tests System).

tor. Tests essentially consist of (1) generating stimulus, (2) programing the exact destination to which the stimulus will be sent, and (3) evaluating the specimen response to each stimulus.

Results of the tests are decoded, stored, displayed, and/or printed out on hard copy.

In the case of the r-f data-link interface subsystem, stimuli will be in the form of an r-f interrogation of the specimen under test. Specimen return to APATS is stored on video tape and simultaneously translated by pulse-amplitude-modulated telemetry apparatus into analog messages representing the data being transmitted.

APATS consists of five major subsystems; a system test control unit, an r-f data-link interface system, a tape recorder console, a power distribution console, and a mobile unit containing the peripheral equipment. An overall block diagram of APATS is shown in the accompanying illustration.

The system test control unit is comprised of a main junction box, specimen power supplies, signal distribution console, and a system programer. The system junction box receives voltage-monitoring and sensor lines from the specimen. These lines are routed to the signal distribution console.

Outputs from the lines are available at a patch panel on the distribution console where they can be monitored, recorded and, as necessary, controlled. Monitoring, recording, and evaluation of specimen-activation events and specimen malfunctions are performed by this console.

The programer console performs the function of a central programer-comparator. In addition to remote control of the other APATS consoles, the console automatically performs all of the comparison and evaluation measurements of the specimen function. The programer can control the selections of stimuli, select test points to be monitored, and determine program continuation in accordance with the measurement and evaluation results.

The r-f data-link interface system consists of a uhf telemetry console and a pulse-amplitude-modulation (PAM) console. The uhf telemetry console transmits self-contained, preprogramed command messages to the specimen by means of coaxial cables. It is also capable of performing wide-band and narrow-band evaluation of power, frequency, and frequency deviation of the PAM telemetry wave train received from the specimen.

The PAM video is recovered and sent to the tape reader console for storage, and to a discriminator for demodulation. The resulting pulse amplitude signal is fed to the telemetering console, where it is processed for main frame and subframe separation.

Eleven of the possible 2048 channels are monitored continuously. All of them are processed sequentially and fed to the proper tape punch and to a digital printer for display.

Peripheral equipment contains a uhf telemetry receiver and provisions for six discriminators. Output of the receiver can be fed into the uhf telemetry console discriminator for PAM processing.

• **System test control**—The programmer (see simplified block diagram) automatically interprets programed test routines from the tape reader, and then carries out the orders as directed. In performing test routines, the programer: (1) provides stimuli and peripheral equipment control to the other consoles of the APATS system; (2) selects the desired measurement test point, function and range; (3) performs evaluations to determine if the measured parameter is within acceptable limits; and (4) makes decisions—such as which test routine to perform next or when to stop testing—based on the results of each test.

The unit is operated as a bit-serial, character-serial device, which minimizes the circuitry required and increases overall realiability. The bit-serial operation of the programer does not increase the overall testing time of the system, since each character from the tape reader is processed in a fraction of the time that it takes for the tape reader to move from one character to the next.

This is because the tape reader per-

(Continued on page 33)

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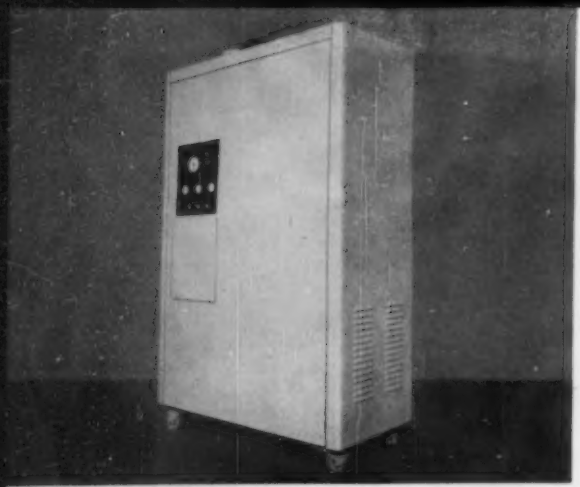

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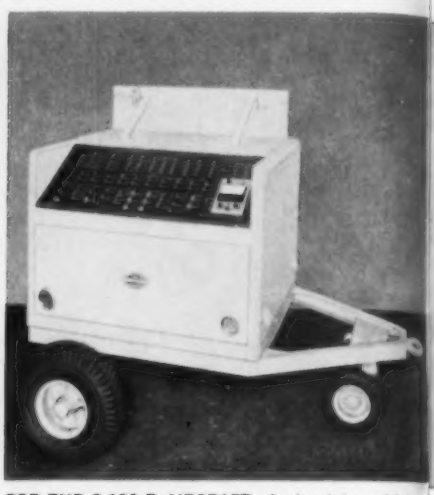

FOR THE C-130-B AIRCRAFT—A simulator which can make 100 electrical circuit checks in minutes.

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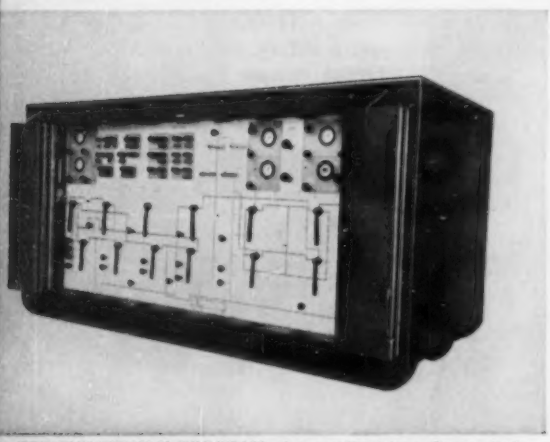
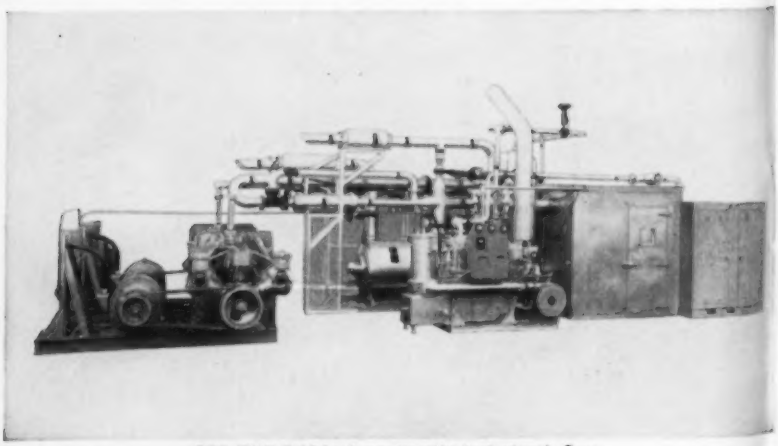
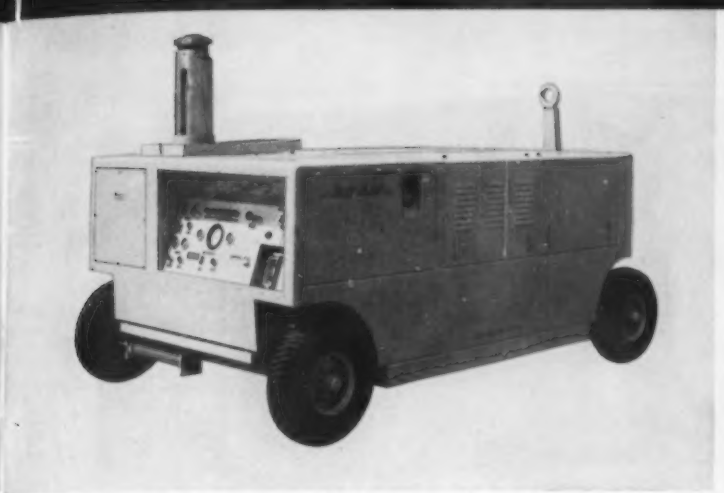


FOR THE TITAN II PROGRAM—A propellant transfer control unit designed to transfer aerozine 50 or nitrogen tetroxide at rates of 61 or 190 gpm at pressures up to 150 psig.



FOR THE F-104—A pneumatic test stand. Simulates flight conditions to functionally check the plane's air-conditioning system during overhaul.



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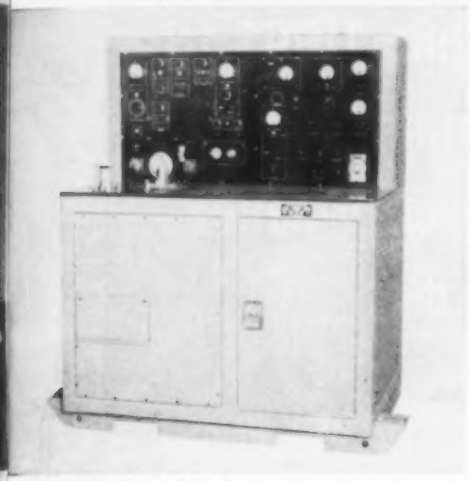

FOR THE B-58—A test stand for functional check out of the plane's temperature-control components.

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A cross-section of the 40 subsystems incorporating 3500 electronic parts which go into TIROS III are framed by two satellites. All components must be thoroughly tested, precisely integrated and must function perfectly if the satellite is to perform successfully.

NASA's Hurricane spotting TIROS III maintains projects' fine performance record

With the successful launching of TIROS III, meteorologists for the first time will see the total cloud formations and measure the radiative energy balance of hurricanes which plague the eastern coast of North and Central America each year. For TIROS III was launched at this time for precisely this purpose. From information gained from TIROS III, meteorologists may learn much more about the birth and life cycle of tropical storms.

TIROS III DESIGN

Although the spacecraft configuration is essentially the same as the previous two highly reliable TIROS satellites, TIROS III has two wide-angle cameras and the National Aeronautics and Space Administration has placed new omnidirectional IR sensors aboard to measure thermal radiation from the earth and sun.

THIRD OF A FAMOUS FAMILY

TIROS III is the third of a highly successful series of experimental weather satellites which were developed, along with the associated ground equipment, for the NASA, under contract with the Goddard Space Flight Center, by RCA's Space Center. All of them have established "firsts" in the United States' space program.

TIROS II established a longevity record for a complex satellite. Still operating after nearly eight months and over 3300 orbits, TIROS II has transmitted over 34,000 photographs to the ground. Aside from its impressive meteorological achievement, historians may well point to this long-term performance as the first to prove that a satellite system could operate reliably for so many months in a space environment thus proving the feasibility of operational satellites.

TIROS I was the first satellite, carrying advanced television equipment, which sent photographs of the earth's cloud cover to meteorologists. From TIROS I's 23,000 photographs, meteorologists found that satellites could be used for weather observation and analysis. The pictorial information is particularly useful in the two-thirds of the world from which few or no weather observations are now available.

CONNOTATIONS FOR THE FUTURE

The TIROS series has proved beyond a doubt that the peaceful uses of space will benefit all mankind. Six nations participated in the utilization of information from TIROS II and more will take advantage of TIROS III. RCA is also already at work on the camera systems and space power supply for NIMBUS, the next generation of meteorological satellites.

If you are a professional physicist, engineer, or mathematician and interested in participating in such challenging projects and stimulating team efforts, contact the Employment Manager, RCA Astro-Electronics Division, Defense Electronic Products, Princeton, N. J. All qualified applicants are considered regardless of race, creed, color or national origin.

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(Continued from page 26)

forms conversions at the rate of 200 characters (frames) per second (actual character read time is approximately 1.7 milliseconds), while the time required to process the character is less than 0.16 millisecond. Thus, a factor of greater than 10 to 1 exists between programer processing time and the tape-reader conversion rate.

In the normal mode of operation, data pertaining to a particular test sequence are searched for and, when located, read into the programer. Tests on the tape are preceded by tape address instructions and addresses, enabling the programer to locate desired data and to sense when to read the data into the programer.

After completing the tape search operation, the programer performs the test sequences stored on the tape.

Overall operation of the programer is controlled by the instructions obtained for either the test sequences, manual commands, or remote inputs. During testing, the program control element obtains instructions from tape, interprets them, and issues appropriate commands to other units. These instructions may be: (1) commands which select particular stimuli, (2) commands which set up other console functions, (3) measurement test-point selection commands, (4) a comparison command, or (5) commands to branch to a new series of tests.

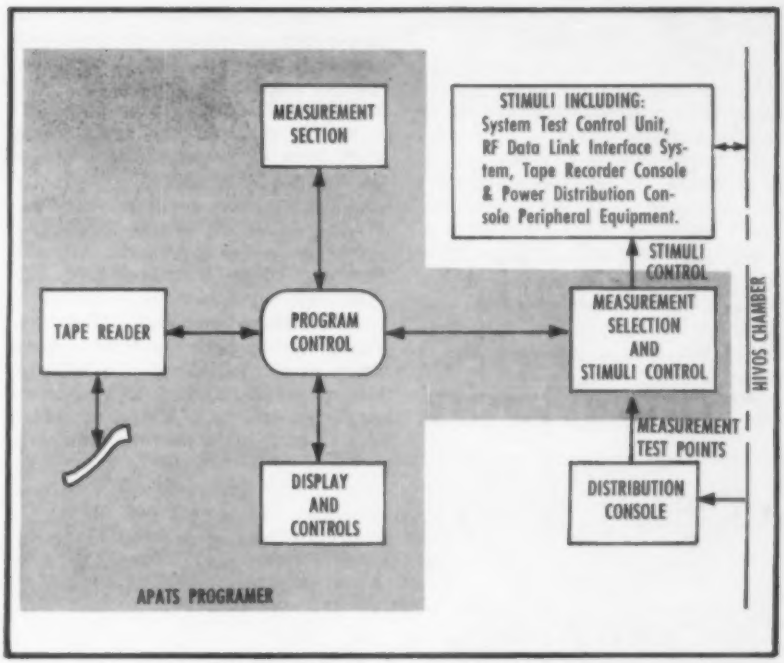
The instruments may also contain "display" or "print" commands, or they may select a particular measurement range and measurement function.

At all times the program control, along with the instructions, controls the flow of data to and from the various units of the system. Provisions for remote control of the program control unit are included in the system for interrupting programer operation until a particular subsystem operation is complete.

A typical test sequence might require data to be routed to the stimuli control unit, which would then select the desired stimuli for the specimen under test in the HIVOS chamber. Next the measurement test-point selector would be commanded to route the proper monitoring point from the distribution console to the measurement section.

The instructions would then select the range and type of measurement, followed by a setting of the upper and lower limits of the parameter to be measured into the appropriate storage device.

After a comparison command, the programer would be instructed to either branch to a new test sequence or continue on to the next test in the original sequence. This process of performing tests from tape would be continued until testing was completed or stopped, or a defective unit was detected.


MEASUREMENT SECTION
STIMULI INCLUDING: System Test Control Unit, RF Data Link Interface System, Tape Recorder Console & Power Distribution Console Peripheral Equipment.
STIMULI CONTROL
TAPE READER
PROGRAM CONTROL
MEASUREMENT SELECTION AND STIMULI CONTROL
HIVOS CHAMBER
MEASUREMENT TEST POINTS
DISPLAY AND CONTROLS
DISTRIBUTION CONSOLE
APATS PROGRAMER

FUNCTIONAL DIAGRAM of APATS system programer.

The system junction box provides terminal points for 990 incoming specimen lines. In addition, it accepts d-c power from the specimen power supplies for routing to the unit under test.

Incoming specimen lines are routed to the distribution console, where any information from the specimen can be monitored, recorded, or controlled. Of the 990 lines, 656 lines are routed from the distribution consoles to other APATS consoles.

Specimen power supplies are controlled both locally and remotely from the programer console.

The signal distribution console receives signals of the specimen function that are routed through its interface connectors. Signals from the specimen umbilical and test plugs are routed via a patch system to their respective connectors. These and other signals generated by the system programer and system test control unit are monitored on the input test point panel with a digital voltmeter and an oscilloscope. The distribution console provides a means for monitoring the squib lines.

• **R-f data-link interface system**—Upon command of the programer console, a message generator converts and clocks the 39-bit parallel message information from the punched-paper tape reader to 37 bits of message. These are fed serially to a voltage-controlled oscillator. The remaining two bits are used to recognize one of four different types of messages. Message-type information is used to gate the 37 circuits that select which bit-time slots will be blocked for each message.

Output of the voltage-controlled oscillator (VCO) is one of three frequencies: 43 kc for a logical "1", 37 kc for a logical "9", and 40 kc for no information. The VCO output is mixed with a 1-kc sine wave, generated by a 1-kc clock in the message generator. The resultant signal is used to frequency-modulate a 1700-1850 mc signal generator. This fm command signal is transmitted to the specimen unit under test via a coaxial cable.

The signal generator output also can be routed to a spectum analyzer and a frequency counter, where its deviation and frequency are monitored during initial adjustments of signal-generator characteristics.

Upon receipt of a valid message, the specimen generates a 10-ms message-acceptance pulse (MAP) which is sent back to the console on one of four lines. Each line corresponds to one of the four different message types.

If the MAP is present on the proper line at the time when the message generator generates a MAP interrogation pulse, a "tape reader advance" pulse is generated. If a MAP is not generated or is not on the proper line, an error signal is generated and the tape is prevented from advancing.

The telemetry console also accepts a PAM/FM/FM signal from the speci-

(Continued on page 67)

GSE SPACE

Takeoff From Moon Relatively Simple

In initial lunar voyage, vehicles will carry fuel for return, other support equipment will be entirely internal

by Robert S. Turner
Electronics Division,
The Martin Company

IT WILL TAKE MONTHS of final preparation, thousands of personnel, and worldwide facilities to launch a manned space vehicle moonward. How can a crew of only three men complete a vehicle checkout and launch their craft from the unprepared surface of the moon?

To answer this question, a comparison may be drawn between the requirements for launching from the earth and those for launch from the moon. The difference is considerable.

• **Mission compared** — The five-stage, earth-launched vehicle will be much larger and more complex than the moon-launched craft. The three-stage booster will lift the spacecraft into an earth orbit; then the third stage will shut down until it is restarted at the precise time for translunar injection. The lunar stages then proceed to a lunar orbit, and eventually a landing.

When the vehicle takes off from the lunar surface, the landing stage will be left on the moon—its last service being as a takeoff platform for the return flight. Thus the vehicle for the return trip to earth will be a relatively simple, one-stage affair. And this reduction in the number of stages directly reduces the complexity of the prelaunch checkout.

• **Detailed checkout on earth**—Before the spacecraft even leaves the earth, prelaunch preparations and final-launch countdown procedures must prove the readiness of the total vehicle to accomplish the entire mission. This is the last chance to look at the individual components of the many systems, to check for leaks, clearances and faulty workmanship and to verify an operation visually as well as by instruments. Specialists on each system must coordinate their activities through a test conductor—who, in turn, is coordinating these activities with those of the support functions (tracking, telemetry, range safety, rescue, computing centers and worldwide communications networks).

The prelaunch tests to establish the readiness of the vehicle to function reliably for the full duration of the mission must be performed thoroughly—and yet rapidly enough to prevent excessive running time on equipment and waste of highly volatile, venting fuels. All of this must be done with no degradation of the tested systems due to error caused by human carelessness, fatigue, ignorance or irresponsibility.

• **Electronic checkout requirement** —Hence the requirement exists for reliable electronic programing, evaluating and computing checkout equipment. Such equipment tests and evaluates component and system operation, locates malfunctions, evaluates performance and records results which are used in external computer programs to calculate and predict the mean time between failures to insure a successful mission. Installation and checkout of these checkout devices is costly and time-consuming, but necessary to ensure the success of this highly complicated mission.

Is all this preparation an adequate basis for assuming that the success of the whole mission—return as well as the outgoing trip—will in fact be ensured? The answer must be a qualified yes—qualified by the consideration that success cannot be predicted with absolute certainty for any such pioneer venture. But the answer, even though qualified, remains yes; for the really enormous extent and thoroughness of the prelaunch checkout calculations puts the probability of success very high indeed.

• **System reliability analyzed**—The mean time between failures for these systems is a known, previously determined value. Test results for the moon-landing systems can therefore be fed into the external computers along with the results of every previous test conducted on the critical system; using performance variations, mean time between failure typical performance characteristics of *all* previous systems, an expectation of no failure during the entire scheduled flight time can be established with almost complete certainty.

Prelaunch GSE establishes not only the absence of any malfunction in the system, but also the existence of any trends toward improper conditions. On-board checkout devices would consist of the telemetering transducers (which read out critical functions) with limited inputs to system functions, test problems programed to check the computers and such normal gauges as Fuel Level, Tank Pressure, Oxygen Level and Power-Supply Voltage. Two complete systems will be provided on board so that the crew is assured of having at least one operable system under the very worst conditions predicted.

In addition to the foregoing types of equipment, the on-board test gear would include a high-capacity, general-purpose computer. The whole complex of on-board test equipment is restricted to making system functional tests. All systems must be checked before proceeding to the next portion of the flight —earth parking orbit, translunar flight, lunar orbit injection, or lunar landing. The crew is able to abort the flight at any point before lunar landing. Thus it may be assumed that the vehicle will be in sound order when it reaches the moon.

Limited on-board maintenance must be possible. The presence of man supplies redundancy through his ability to

make decisions and accomplish minor repairs. This aspect requires much more study to determine what will be done. Weight for spares will be at a premium.

• **Safety considerations** — Another factor leading to a large expenditure of man-hours and facilities for earth launch is safety. This includes safety for those conducting the tests, the astronauts, the bystanders and those people that lie along the flight path of the vehicle. The highly flammable and explosive fluids and solids in the various systems require the use of many remote control devices, additional transportation, guards, etc. Abort, recovery, and retrieval of the spacecraft and astronauts during all operations where earth landing is the final result involves an extremely large force of people, airplanes, ships, helicopters, tracking locating and communications networks able to cover most of the earth's surface.

In contrast, the astronaut team must launch from the moon with no external support. Although there is no safety problem due to external influences, a failure during the launch maneuver from the moon will almost certainly be fatal.

• **Lunar launch checkout**—Assuming that the landing on the moon was accomplished within design limits, a high degree of reliability and confidence will have been established in the spacecraft operating systems, particularly the guidance and control systems. The only real unknown at this point is the lunar takeoff engine. The same type of procedures and systems for checking the lunar landing engine were employed during the flight with the same on-board checking equipment used to checkout the lunar takeoff engine.

The checkout of the lunar takeoff engine will be routine. The guidance and control systems will continue to be employed as they were enroute. The on-board equipment will check these systems. The astronauts' knowledge of their position on the moon will provide an exact reference for any resetting of position or alignment of the stable platform.

The launching of a vehicle to the moon is a very complicated mathematical problem from the standpoint of establishing the trajectory to be flown and the task of determining if the vehicle is on the right trajectory and, if not, just what the correction to return to course will be.

The earth launching is also complicated by the fact that the launching point is continually moving relative to the earth-moon line because of the rotation of the earth about its axis. This fact requires a constant changing of the trajectory to be flown, and therefore a continuous input to the guidance system to provide it with the correct information at launch time. Since the launch azimuth is limited by range safety factors and the desire to miss the Van Allen radiation belts, the allowable time to launch is restricted to a few hours a day.

• **Lunar launch simpler**—Although the accuracy requirement for guidance from the earth to the moon and the moon to the earth is approximately the same, the launch from the moon is not as complicated because the moon does not rotate relative to the earth-moon line.

This difference is very important because it eliminates the requirement for continuously changing inputs to the guidance system to obtain the required trajectory to earth. The proper launch azimuth can be preset for the particular moon launching point. At this point time becomes the only variable, in order to launch on the trajectory that will return the vehicle to earth along a particular trajectory approaching a present landing area from a particular direction. A variation in the launch time will change the direction of approach to the landing area and will require a change in the point at which trans-earth injection is accomplished.

This fact allows the astronaut crew to use information precalculated and available to them in tabular form. Therefore, the ground support of a computing device will be eliminated.

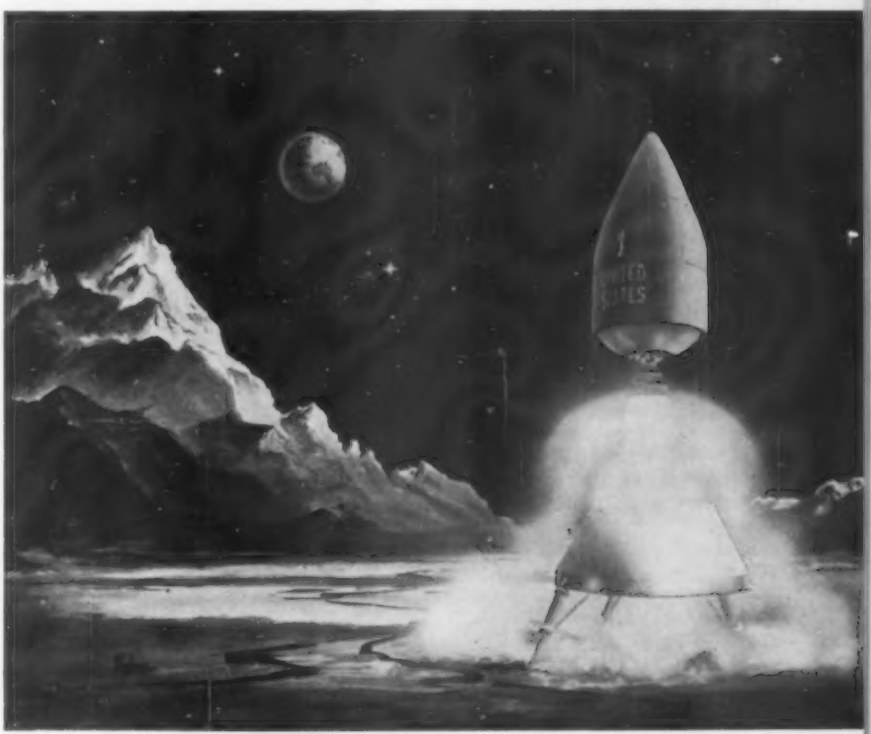
It is interesting to note that the vehicle can launch from the moon on a present azimuth at any time and return to the earth's atmosphere, although the crew will not have a selection of landing site under such a condition. However, this is of prime importance in the case of an emergency situation—such as a dangerously low supply of oxygen —in which case immediate return is necessary.

• **Further considerations**—The present state of the art of orbital mechanics and of guidance, control and propulsion systems, and our lack of knowledge of the moon's surface make it seem impractical to assume that a lunar landing spacecraft could expect to be refueled on the surface of the moon.

First of all, we do not now have the capability to spotland a load (or, more likely, several loads) that the first astronauts could hope to find or assemble for use in the time allowed for the initial stay on the moon surface. Also, emergency situations for immediate return must be met with the capability of launching very soon after landing. Therefore, the initial lunar landing craft must carry its return fuel and all the support equipment.

The lunar landing and takeoff must be similar to an aircraft intermediate landing and takeoff. There must be

(Continued on page 68)



ARTIST'S CONCEPT of early blastoff from moon shows how only lunar support equipment will be landing stage, serving as takeoff platform for return trip.

Mariner Support Will be Tailored

JPL has set up 12-phase program for developing spacecraft and support equipment in close coordination

SUPPORT EQUIPMENT for the *Mariner* Venus probes will be closely linked with the laboratory test equipment used in developing and testing hardware.

A high percentage of *Mariner* GSE will be supplied as individual test and checkout components by contractors furnishing a specific subsystem or scientific experiment for *Mariner*. In this way, support equipment will be tailored to the exact needs of the spacecraft and its payload.

Following the successful test and acceptance by Jet Propulsion Laboratory of each subsystem or scientific instrument package for *Mariner*, the contractor-supplied support equipment will be "packaged" for ease of use.

Instrumentation-checkout GSE will be integrated into a single, multi-function unit to enable rapid test of *Mariner* payload subsystems and instrumentation.

The narrow time envelope available for *Mariner* launches—the period during which the necessary reference planetary bodies are properly aligned—demands fast, integrated checkout of the instrumentation. All power supplies to the instrumentation, for example, must be validated simultaneously. Time is too precious for leisurely examination of each circuit once the ideal launch envelope is reached. Detailed checks will be accomplished in early phases, and repeated many times before launch.

GSE for the spacecraft itself will not require the high degree of integration necessary in the instrumentation packages. It will probably be semi-integrated for compactness, since the relatively low usage rate makes it uneconomical to spend many engineering hours on special packaging. Standard size, rack-mounted modules are believed sufficient. However, time will be spent on developing accuracy and reliability in support equipment.

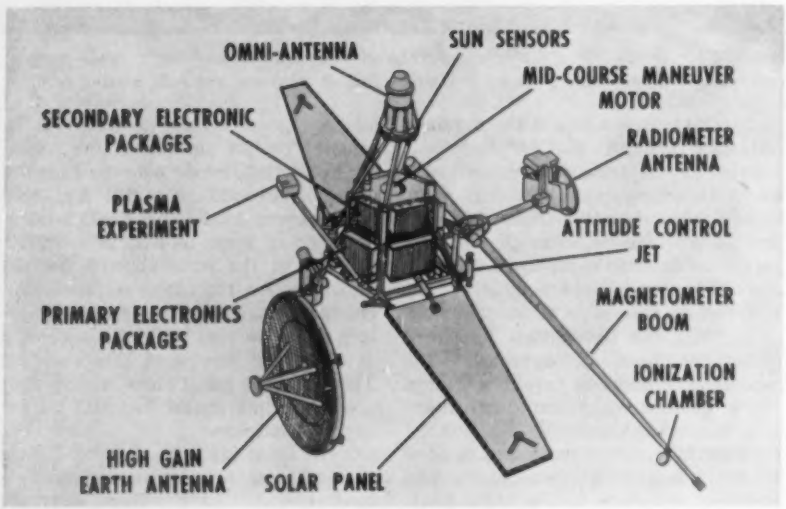
• **Hand-in-hand approach** — It is believed that few new techniques will be involved in the checkout of the *Centaur* or *Agena B* vehicles, other than those required to satisfy the program's built-in need for accuracy with speed. However, the JPL program for *Mariner* GSE does differ in many respects from less demanding space vehicles.

Mariner GSE and developmental test equipment are virtually one and the same thing. JPL's newly completed space simulation chamber performs a ground support function for *Mariner* and other interplanetary programs. Other special items include a device for testing minimum-force actuation of *Mariner's* extension arms and booms, and a mockup of the *Centaur* for compatibility tests.

JPL has laid out a 12-phase test and development program for *Mariner* in which the spacecraft and its GSE will be developed hand-in-hand. With this approach, the primary difference between the development program and a pre-launch checkout becomes just a matter of time. The steps will be almost identical, as will much of the launch-site GSE.

• **First push**—The program, designated the Formal Systems Test Phase, is closely timed. The first big push comes in Phase 1—assembly of equipment and hardware—in JPL's assembly building. During this period, considered a test phase because problems of a mechanical nature will be solved, the first use of a piece of directly-related *Mariner GSE*—such as the primary test fixture—is brought into play.

Phase 2—scheduled for 7-10 days—is the Systems Test Complex Checkout: verification of test complex workability. GSE units will be checked out



DETAILED DRAWING shows Mariner equipment needing GSE.

to Needs of Vehicle and Capsule

and calibrated to make certain that the spacecraft subsystems and experiments will not be exposed to catastrophic damage. All electrical connections and leads will be checked for specific voltages at the correct pins. This phase is critical, since *Mariner* will have few standby components or spare assemblies to replace items damaged in testing "accidents."

When Phase 3—initial "turn-on" of the spacecraft—is reached, extreme caution will be exercised so that power will be applied gradually, in planned steps. The spacecraft's ring harness will first be engaged with no subsystems connected.

All crucial input voltages will be verified with meters at harness leads to prevent damage. Dummy loads will be connected to the ring harness after the basic power supply has been plugged in and the inverter checked out satisfactorily. Special attention will be paid to any serious degradation of the power and voltage loss during this portion of the test.

• **Plugging in**—Next, actual "black boxes" are plugged in, one at a time. Each is then energized for a continuous period of several hours to observe basic operation. This portion of Phase 3 can be compared to laboratory bench tests with these exceptions:

—Assemblies are physically mounted on the spacecraft, providing a degree of systems integration.

—The *Mariner* power supply is used for the subsystems and experiments.

—Power is fed through the actual ring harness.

During the latter part of Phase 3, each *Mariner* subsystem undergoes a more careful checkout. Various inputs and outputs are routed through the spacecraft circuits, rather than synthesized on a bench. Loads and signals are then applied to the final subsystems, which comprise some 75-80% of the entire spacecraft system. Follow-up circuitry, such as amplifiers and analog-digital converters for some of the scientific instruments, is placed into the system during this phase.

• **Key subsystem**—Checkout of the ring harness is an extremely sensitive area. In several past satellites this assembly has been increasingly troublesome as spacecraft designs became more complex. Therefore, much thought and effort is going into the *Mariner* harness—considered by many the most important subsystem in the spacecraft. It will receive special attention in eight of the 12 test phases and will consume a large total of the scheduled test hours.

Since a careful balance has to be achieved between shielding for the circuits and weight and size limitation, the ring harness for the spacecraft subsystems and scientific experiments must be tailored to the specific installations. This means a sizeable total weight. Each circuit must be analyzed to provide a "Signal Characteristics Data Sheet" specifying voltage, current, wave shape, rise time, and other parameters for that particular circuit.

Squib circuits—controlling nearly all mechanical releases, extensions and actuations—cause many of the circuit problems. Due to the short, heavy surges of current triggered through the squibs, the *Mariner* squib harness will have to be routed independently from the main harness to reduce the effect of its inductive fields on other circuits.

Phase 6—initiating the Formal Systems Test during which the flight sequence will generally be followed—is designed to compress the time required for a particular action to a practical value. The Central Computer and Sequence (CCS) in particular is one of the items that can be speeded up for the programed 180 days transit time to reach Venus. The CCS is designed to be "jumped" to a future time or shifted into an operational speed 15 to 25 times faster than normal. Three weeks is allowed for Phase 6, but it is hoped that one week will be sufficient.

• **New gimmick**—In addition to the umbilical cable link from all leads to the GSE and the telemetry link, a new system will be introduced on *Mariner* —direct access to "cases" installed in the spacecraft with internal leads to important circuit points. These pick-offs will give the testing personnel—both JPL and contractors—the ability to run test leads back to that part of the GSE which corresponds to a particular subsystem.

These parallel test leads will provide sufficient isolation to minimize the effect of the GSE. Specifically, the testing area can monitor the subsystems without disturbing them, thereby leaving interfaces undisturbed. The access leads will be left on until Phase 9 is started.

Phase 7—weight, CG, and Moment of Inertia measurements—enables JPL technicians to calculate these parameters very precisely to insure that they fall within specified limits. Also, during this phase the exact size of the exhaust throats in the gas jets of the attitude control system will be determined.

• **Chamber debut**—Phase 8 will mark the first use of JPL's new space simulation chamber, when the *Mariner* and its GSE is moved into the new facility for Environmental Tests.

A major objective of these tests will be complete thermal isolation of the spacecraft in order to simulate the environment of deep space. The special pedestal on which *Mariner* will be mounted is to be cooled by liquid nitrogen matching the supercold of the surrounding chamber walls. There will also be a thermal barrier between the spacecraft and the pedestal, to insure uniform temperature on all surfaces of the spacecraft.

Even the direct access leads from the GSE to the subsystems and experiments will be conditioned to the space environment by the use of a special conduit cooled by liquid nitrogen on its exterior surface. However, the interior of the cable carrying the wires will be maintained at the same temperature as the spacecraft interior by the use of heaters in the cable.

Extreme care must be exercised in placing these cables to eliminate the shielding effect they might introduce in relation to the cold walls or the heat of the simulated solar radiation entering at the top of the chamber. The spacecraft will be operated as if it were in flight, with some events compressed in time.

• **Trial by shaking**—Following the space environment tests, the spacecraft will be returned to the assembly building and subjected to vibration tests. It will be run through a streamlined systems test—again compressing in time many of the events—while undergoing both low-frequency and high-frequency vibration tests. The JPL hydraulic

(Continued on page 67)

Prospector May Haul First Moon GSE

NASA considers possibility of making program's major goal the support of manned lunar expeditions; a look at 'LSE'

NASA'S *PROSPECTOR* may take the first "ground" support equipment to the moon, where it might even provide men with a means of transportation.

Although it was conceived originally as an unmanned lunar exploration program, space officials now feel that *Prospector* may be replaced in this role by its predecessors, *Ranger* and *Surveyor* (M/R, Aug. 14, p. 37).

NASA is giving increased thought to another part of the *Prospector* concept: its use as a means of support for the U.S. astronauts who are due to be landing on the moon at about the same time (1966-67) that the first *Prospectors* are scheduled to be launched.

This envisions landing supplies for a manned expedition aboard the *Prospector* carrier vehicle. It could also include using the originally planned unmanned lunar surface vehicle as "wheels" for the human explorers.

Pending the government's decision on exactly what *Prospector's* mission will be, industry firms involved in it describe their studies as "*Prospector*-type." Company spokesmen are also a bit reluctant to discuss their plans in great detail because of proprietary thinking toward the program's payoff.

Nevertheless, planning has proceeded rapidly and proposals are well advanced.

The planners all agree that very little new support equipment will be needed for the lunar exploration phase of *Prospector*—if that phase is carried out—but that the earth-based equipment will have to be highly reliable.

• **Stations on overtime**—As the lunar-based vehicle moves over the surface, the moon will be visible to earth tracking stations for approximately the time it takes the sun to move from horizon to horizon. This means that transfer of control from station will not be as frequent as with lower satellite orbits. But it will require that each station remain operative for periods of 8-12 hrs., rather than the "on" for 15-20 min., then "off" for 90 min. or more.

Companies with *Prospector*-type studies are quick to point out that there are no fundamental limitations for earth-based receiving stations. The present National Aeronautics and Space Administration/Jet Propulsion Laboratory Deep Space Instrumentation Facility (DSIF) will do the job. But there are other factors.

If the DSIF stays with its present 85-ft. antenna system, it will boost power requirements for the *Prospector's* lunar exploration vehicle. If the full 250-ft. antenna system is completed in time, the moon vehicle's TV power requirements may be cut by about 10%. A *Prospector* operation would not be "limited" by use of the 85-ft. antenna, but the vehicle power requirements could be considerably altered.

There may be a loading problem at earth facilities if the *Prospector* vehicle has a very limited life before fuel pellets evaporate, batteries run down, or drive motors wear out. It will be necessary to obtain all data possible, as well as control the lunar-based vehicle's surface explorations, during this lifetime. It cannot be allowed to "just sit and deteriorate."

This presents the possible problem of tieing up the earth-based communications net—eliminating it for any other work. But, industry studies indicate this can be solved by adding extra receiving equipment and data recorders, including a large amount of video tape systems for TV data.

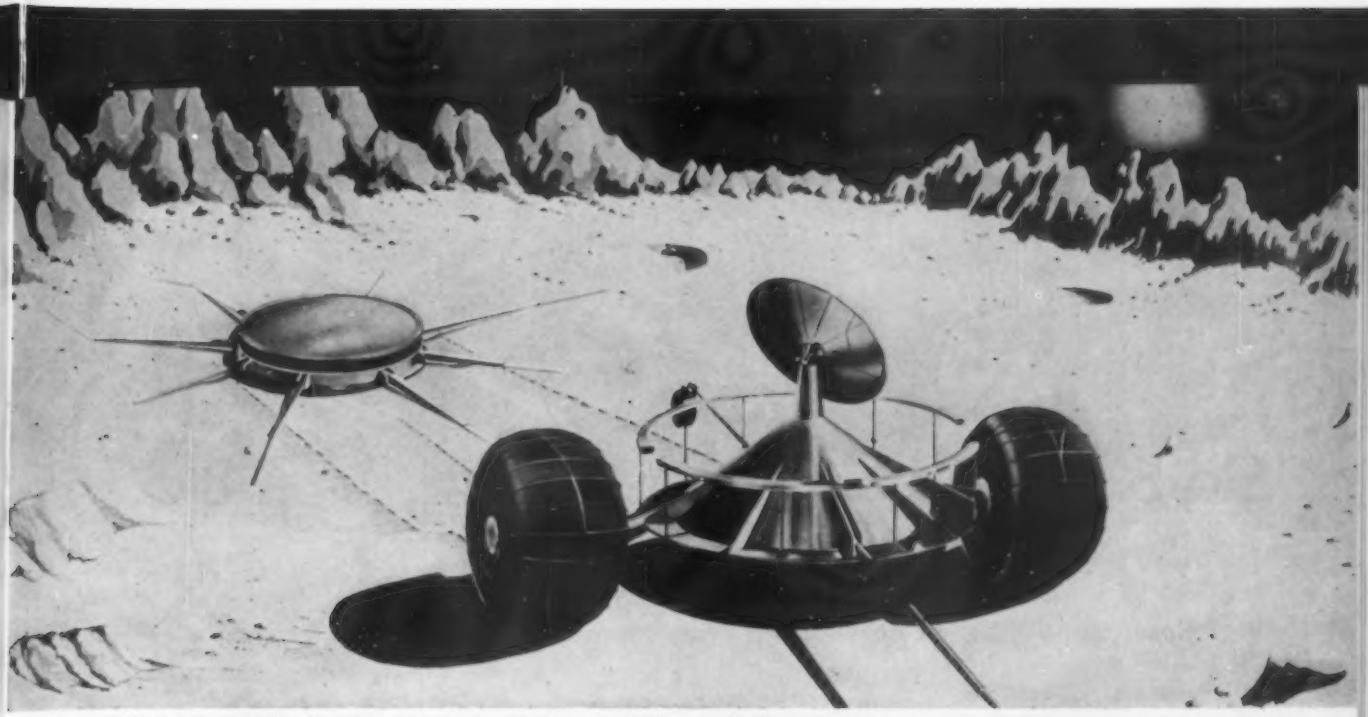
The DSIF has, in its present form, sufficient band width to handle *Prospector* data and control functions for TV scan, vehicle velocity, and other operations. Bit studies also note that this factor is a wide variable. It would be simple to design a roving vehicle (lunar) that could transmit more information than could be handled with a "reasonable" earth station. But, for what industry studies indicate as a "logical" mobile lunar vehicle, the DSIF net is satisfactory.

Other than an increase in the amount of data equipment installed in tracking and control stations, little new will be needed. But a very large amount of data will be received. If everything the huge amount of video tape data recording system will be required for the huge amount of videa tape data received as the vehicle rumbles about the lunar surface.

• **Seats for kibitzers**—DSIF stations will likely require a rather complex control console and data display system to enable operators to make intelligent decisions while the vehicle moves about the moon. As one scientist puts it: "By the time you add enough grandstand seats behind the operator for all the kibitzers telling him to 'watch out and don't knock into that rock over there' you're going to have quite an auditorium."

A large installation will be needed in DSIF stations for data links, data processing, data recording, and "quick look" processing for some readout in the form of what the operator has to do to drive the vehicle.

The monitoring system will not be



ARTIST'S CONCEPT shows Prospector-type vehicle as it travels over the lunar surface.

like the multi-function, short-flight, *Mercury* system. The time element, although critical, is not extremely sensitive.

• **Easy inspection**—One advantage of a *Prospector*-type lunar vehicle is that it may be stopped at any time a decision is required. The vehicle may be "parked" while a difficulty is diagnosed.

"It won't go away," an engineer told M/R, adding that this is a "big factor in accomplishing the vehicle's mission."

"If you have, for example, a squeaky right rear wheel, you can run the vehicle back and forth to decide what you should do about it. The only risk you take is the possibility of some propellant boil-off, but you don't have to rush about such things—and this is a big, important factor."

• **GSE vs LSE**—Scientists and engineers draw a fine line between GSE and lunar support equipment (LSE) for *Prospector* and other, future, manned or unmanned programs. The trend is towards terming such equipment LSE, despite the more commonly accepted GSE tag. In general, all equipment with the exception of "the rocket to get him there and the one to get him back" is support equipment.

It is fairly obvious that manned lunar operation will require about as much equipment as operations on earth. But the equally obvious differences are receiving much study.

Firms queried by M/R are in complete agreement that there is sufficient knowledge of the lunar environment to help in working out problems. There is equal agreement that there are probably some "specific little things" that are not known. These, however, are felt to be relatively unimportant at the moment.

LSE cannot take what might be considered the "crude" form of GSE for earth-based satellite or ballistic missile operations. The cost-per-pound of putting such equipment on the moon is prohibitive.

The per-lb. cost will probably have the greatest effect of all factors on GSE/LSE—no matter if it is canned soup or rocket propellant. The dollars-per-lb. to put it on the moon are the same.

A little-studied area, according to some firms, is the need for machine tools at a manned lunar base. There is little chance that it would be possible to tote a cast-iron lathe to the moon. The payload penalty would be too great. In addition, the lunar environment will result in equipment with an appearance very different from that of support equipment as it is known today. LSE will have to be designed to the structural weight criteria as present missiles and spacecraft.

• **Premium on imagination**—The problem here is how to design equipment without previous experience—LSE has not been done before. The solution, firms queried by M/R said, is to divorce present thinking and LSE design. The basic approach is: "Here I am on the moon—it has cost me 'X' dollars per lb. to get my stuff here and what do I have?"

There is little thought of using exotic materials in LSE. Conventional materials will probably do the job. The only limitation will be the degree of engineering imaginativeness.

"If a new material comes along, we may use it," is the basic philosophy. But the problem is far removed from metallurgical development necessary for boost-glide vehicles, for example. The moon has a "nasty, but not extreme environment."

An early approach to GSE/LSE was to rely on multiple vehicles and cannibalizing, but industry studies now rely heavily upon such planned vehicles as *Saturn* and *Nova*, which will put down enough tonnage in one mission to support a multi-man lunar station.

The big boosters will have an advantage at the lunar end, also. It is expected that the terminal vehicle will not burn out completely. This may mean something like 2000 lbs. of propellant remaining at lunar landing. It may also mean that a big booster will be able to drop an unmanned lunar exploration vehicle on the moon surface, complete with its own fuel—but that there may be enough fuel remaining in the landing vehicle to supply additional vehicle fuel, hydrogen and oxygen for a water source, breathing oxygen, and coolant for electronic gear.

With the "proper" propulsion system in a lunar exploration vehicle, even 500-1000 lbs. of propellant remaining after a lunar landing could run a lunar surface exploration vehicle for 500-1000 mi., according to some estimates.

Until the *Prospector* program is given a fully delineated mission, GSE/LSE studies must be a bit vague. Some firms believe they have all the answers no matter what path is selected—others are not so sure. Few are talking in specifics, but all agree that GSE/LSE will be developed in scheduled, small steps. There are no precedents. ¤

Skybolt on Its Own Once Aboard B-52

Air-launched missile's support will tie in closely with those of aircraft; test gear integrated

by Frank G. McGuire

TEST AND CHECKOUT procedures are being molded for *Skybolt* to support a "hands-off" policy once the ALBM is on its aircraft.

Skybolt—being developed by Douglas Aircraft Company for the Air Force Aeronautical Systems Division—will be tested mainly on the ground, with only an automatic assurance check in the air as part of the launch sequence.

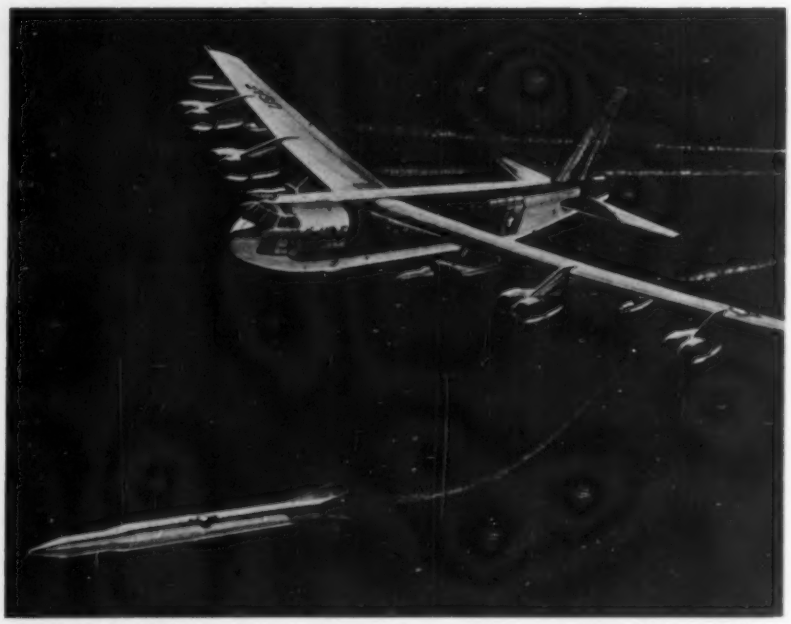
In view of the rapid reaction time and minimum maintenance turn-around time allowable on SAC's weapons, the ground tests on both missile and aircraft equipment have been automated. Once loaded aboard the B-52, the air-launched ballistic missile will stay on its pylon until definite indication of a malfunction or the arrival of a scheduled periodic maintenance date. Ground assurance checks are possible only on installed missiles and aircraft utilizing ground power and cooling carts.

Skybolt will be used by SAC Strategic Wings. Ground support requirements will be handled by integration into existing facilities, thus eliminating any large financial outlay for special buildings or other structures and facilities.

One of the most rigid requirements for *Skybolt's* deployment is that the missile must not degrade the performance, alert time, turn-around time or other factors of the B-52 vital to SAC effectiveness.

S. L. Gehring, Douglas' project engineer for the *Skybolt* support system, said this goal will be met by integration of the support functions into those of the aircraft maintenance cycle and by the use of automatic fault isolation equipment.

Douglas has conducted a detailed reliability analysis of anticipated black box failures. Support equipment and spare parts are to be provided so that a SAC base will be able to handle most *Skybolt* repair and maintenance requirements within the required maintenance recovery time.



INERT SKYBOLTS—as shown in this artist's conception—were dropped from B-52s in series of tests just completed at Eglin AFB, Fla. Target was 15-mile long bombing range.

In those cases where repair by base Air Force personnel is not recommended, the hardware has been so designed that the smallest practical part is removed and returned to the depot.

By this method, *Skybolt* can be maintained at maximum readiness with a minimum of major equipment spares in the supply pipeline. Modular construction using standardized components has aided in this achievement.

• **Subcontractor policy** — Douglas has followed the policy of having each major subcontractor build the test equipment necessary for checking out the portion of the system provided by him. Test units specified by Douglas, using Douglas construction details, are integrated into the overall system.

Some of the major subcontractors associated with the *Skybolt* program are: Aerojet-General Corp., J. W. Fecker Division of American Optical Co., GE/Philadelphia, GE/Utica, IBM, Motorola, Nortronics Division of Northrop Corp., and Texas Instruments.

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Left—The scene: UTC Development Center. The action: static firing test is monitored on closed-circuit TV in Remote Control and Data Acquisition Center.

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the support equipment has been on human engineering, since operation of the equipment will be by Air Force base personnel. Existing SAC maintenance units now servicing the B-52 Strategic Wings will handle the missile system maintenance. A major design consideration is the avoidance of unnecessary complication of already demanding flight duties.

• **B-52 black boxes**—Approximately 15 black boxes containing control equipment are carried by the B-52. They range in weight from 25 to 250 pounds. The equipment is almost completely digital and automatic, and is operated by several control panels. Incorporated as a part of the control functions are monitoring circuits which, in case of malfunction, automatically indicate to the air crew sufficient fault isolation to permit evaluation of the performance capability.

An automatically sequenced missile simulator is used to check out all B-52 *Skybolt* equipment within the aircraft. In conjunction with the capabilities of the aircraft-mounted equipment to monitor its own functions, and by utilizing secondary test-point connections within that equipment, the missile simulator can evaluate performance and isolate malfunctions directly to a replaceable module.

• **Missile Checkout**—The missile itself will be thoroughly tested through a technique which utilizes, for the first time, an AN/GJQ-9 Checkout Sequence Programing Set. This equipment, the first of such to be bought in quantity by the Air Force, will serve as a core for *Skybolt* missile tests and selected module tests with suitable adapters specified by Douglas for specific *Skybolt* test operations.

The Q-9—as it is called—is expected to find almost universal use for checking ballistic missiles by providing a standard tape-programed test controller and measurement standards which are common to all missile checkout procedures. Adapters are used to apply the test functions to the specific missile or subsystem under test.

• **Basic Q-9 make-up**—Built by the Bendix Corp. to meet an Air Force requirement, the Q-9 was first delivered in January, and enables semi-skilled personnel to thoroughly check out an entire missile. Major gains are effected over standard test equipment through reduced test time, reduced operator skill and reproducibility of test sequence and results. Bendix says that the Q-9 can conveniently, accurately and automatically control any desired subsystem test program or checkout sequence verification.

The basic makeup of the Q-9 consists of a tape reader, power supplies, solid-state circuitry and a tape printer, all located in 20 drawers distributed throughout five bays. The equipment is packaged in a two-bay operator's console and a three-bay measurement and selector section. Each of 18 drawers contains one or more test control functions. Two drawers are left empty to allow for expansion.

Used in conjunction with the Q-9 in a particular test is an adapter which supplies excitation and/or control to the item under test, provides stimuli for test inputs, converts output signals, where necessary, into forms acceptable to the Q-9, and provides dummy loads.

Binary-coded test-program tapes are used in the Q-9. Operation of the tapes can be conducted automatically or stepped one frame at a time for semi-automatic operation. Manual test controls have also been incorporated.

• **Test sequence control**—The test sequence from the tape unit is controlled by logic and memory circuits which perform the functions of selection of proper stimuli controls, test-point measurement channels and measurement devices; energizing of timing circuitry; inserting measurement tolerances; regulation of test continuation based on acceptability of the test; and displaying of test data on visual and/or printed readout devices.

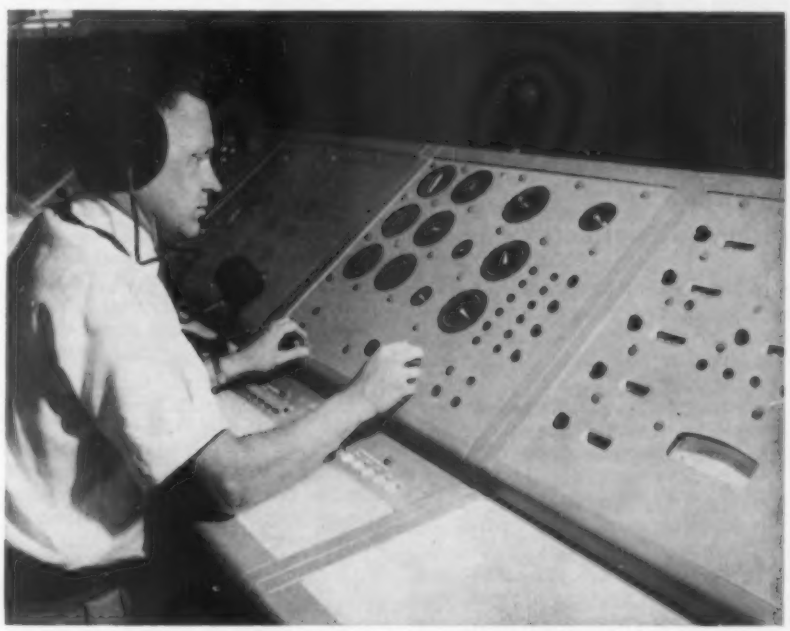
The measurement and evaluation of a test answer involves a simultaneous comparison with prescribed high and low tolerances, with a resultant decision as a go or no-go output signal. Measurement evaluations can be made on a-c voltages, d-c voltages, frequency, time intervals, events per unit of time, resistance, voltage ratios and in-phase and quadrature voltage.

A data readout system provides pertinent test status and results as either a visual readout or a printed readout for record purposes.

• **Q-9 checkout capacity**—Other features of the system include an auto check of programed actions as executed against the tape through a feedback system; an automatic parity check to detect tape error due to wear, misuse or improper preparations—as well as a capability of self-checking the entire set to insure proper operation or to locate a fault to a replaceable module or part.

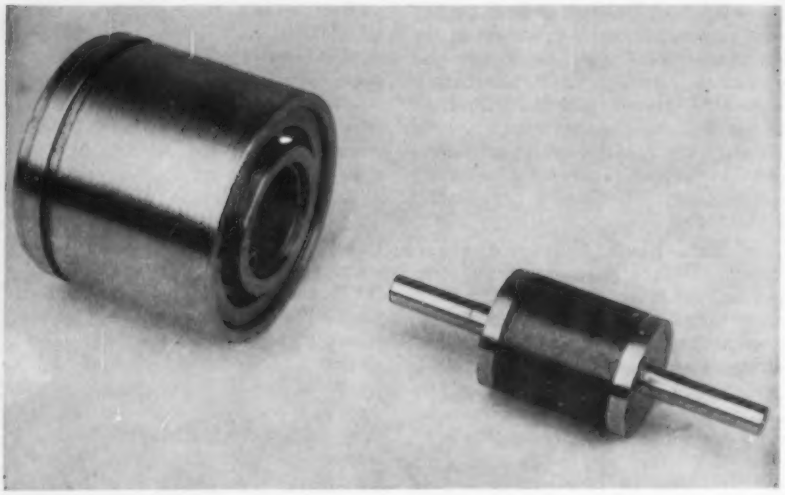
The Q-9 has a capacity of selecting up to 2000 test points for measurement and may include up to 300 channels for stimuli control through the test adapters. By adding an additional bay, the equipment is multiplexed by a factor of ten for *Skybolt* and has a capacity of 20,000 test points and 3000 stimuli control channels.

When *Skybolt* becomes fully operational in 1964, the Q-9 will be used with specific adapters for factory, depot and base, test or checkout. This equipment combined with a missile simulator and built-in self assurance tests in the aircraft mounted equipment help assure that the *Skybolt* system will meet the exacting SAC requirements. ⠿



To Teach Sailors ASROC

INSTRUCTOR'S CONSOLE for ASROC trainer gets final check at Minneapolis-Honeywell Ordnance Div., Duarte, Calif., prior to shipment for installation at Norfolk Navy base. Tactical situations involving the ASROC antisubmarine rocket are established, monitored and controlled by instructors at this master console.



STATOR and permanent magnet rotor of a Hall-effect synchro transmitter

Progress Report on Hall-effect Devices

Kearfott leap-frogging shortcomings of wound rotating components

by Sigmund Harac

Group Leader
Kearfott Div., General Precision, Inc.

WOUND ROTATING components are prominent and significant in modern computing, control and data transmission systems. However, even though there have been substantial improvements in the design of these components —and the improvements are continuing —there are inherent limitations as to the extent to which wound rotating components can be enhanced in reliability, size, accuracy and versatility.

One of the major limitations on reliability is the wear in the brushes and slip rings. Accuracy is limited by the presence of quadrature components, which prevent servo error signals from reaching null conditions, as well as generated speed voltages. The speed-voltage effect—a function of the ratio of rotating speed to carrier frequency—affects both the amplitude and phase of the output voltage and therefore introduces error into both the in-phase and quadrature components.

• **Wound component limitations**—Accuracy requirements limit the extent to which the size of wound rotating components can be reduced. Temperature dependance constitutes a further operating limitation, and significant deviation from normal operating temperatures generally results in shifts in the electrical zero point—accompanied by degradation in electrical error.

The operable frequency range is generally quite narrow. For example, a synchro designed for 400-cycle operation undergoes a derating in excess of 10 to 1 when operated at an excitation of 60 cycles. Operation of the 400-cycle unit at frequencies several times above the design frequency is again unfeasible.

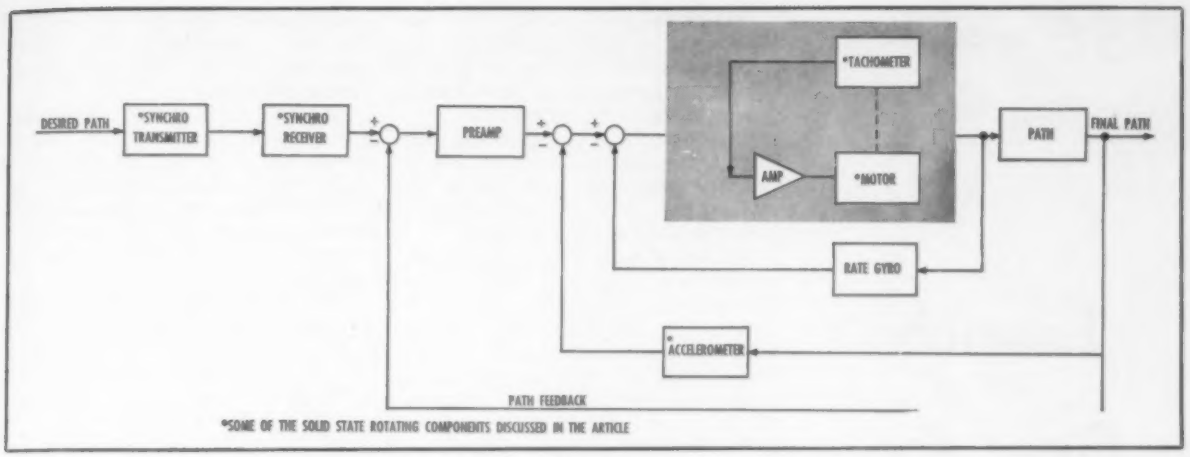
In view of all of these limitations Kearfott has conducted development work for several years in the area of solid-state rotating components, based primarily on the Hall effect. The components are designed to overcome all the limitations of the wound devices. They are being constructed to operate without brushes or slip rings, and will have negligible quadrature components and speed-voltage effects. Their temperature dependance can be greatly minimized, and they can operate over a wide range of frequencies. In addition, they can be made smaller and cheaper than their wound counterparts.

• **Hall effect described**—This phenomenon occurs when certain materials are subjected to a control current and a transverse magnetic field, with the result that a voltage is generated at right angles to both the current and field, having a magnitude proportional to the vector product of the current and field. This effect came into its own with the advent of modern semiconductor materials, whose parameters are such that the output voltage is raised to a useful working level, and which permitted the elevation of the Hall effect from a laboratory curiosity to a powerful design tool.

The Hall-effect generator—the heart of the solid-state rotating components described herein—consists basically of a slab of semiconductor material with a pair of electrodes for the introduction of control current and a transverse pair of electrodes for the Hall voltage output.

By placing the generator in magnetic fields and varying the overall configuration, it is possible to simulate, and and improve upon, the performance characteristics of conventional wound rotating components. The Hall-effect generator acts as the transducing element, and since it is essentially non-inductive and non-capacitive in nature, no significant quadrature components or speed voltages are generated as it is rotated in the magnetic field.

• **Material selection important**—By selecting the proper semiconductor material—doped to the proper impurity



BLOCK DIAGRAM of airplane pitch steering control system.

concentration—it is possible to obtain operation over very wide temperature limits. Generally speaking, the selection of the material and doping concentration depends on the specific end use, and normally represents a compromise among parameter requirements such as voltage output, temperature dependance, magnetoresistance properties and output impedance.

The materials most frequently encountered in commercially available Hall-effect generators are indium antimonide, indium arsenide and indium arsenide phosphide. Germanium is the material most commonly used in the special generators developed at Kearfott for use in solid-state synchros for the Bureau of Naval Weapons.

At a fixed-frequency operating field, the Hall voltage output frequency will be determined by the frequency of the control current. The device will operate without significant derating over frequency ranges approaching the megacycle range. The same solid-state resolver, therefore, can operate equally well at dc and 10kc by simply varying the input control current from dc to the higher frequency.

The solid-state rotating component can be constructed with a stationary field structure and rotating Hall-effect generator, or vice-versa. In the latter type of construction, it is possible to replace the electromagnetic structure with a ferrite permanent magnet, and thus eliminate the requirement for brushes and slip rings. The permanent magnet must be magnetized in a special manner in order to ensure the correct flux distribution in the air gap.

• **Components under development**—Among the many solid-state rotating components in various stages of development are synchros and resolvers, brushless dc motors, tachometers and accelerometers. The synchros and resolvers generally consist of ferrite rotors and Hall-effect generator stator assemblies. The output from the generator varies sinusoidally as a function of shaft rotation because the component of the magnetic field normal to the control current varies as a sinusoid. By properly positioning these generators with relation to the field, it is possible to obtain a sine output from some transducers and cosine output from others.

These units are not intended as direct field replacement for existing precision wound components because, with the present state of the art, the output levels are substantially lower than in the wound counterpart. In addition, there are impedance matching problems. Rather, the solid-state components are envisioned as building blocks in overall solid-state control systems, incorporating the various operational advantages described above.

• **Design considerations**—The development of solid-state rotating components introduces several special design consideration and unique problem areas. It has already been mentioned that the output voltage levels are lower than those of similar wound components. Specifically, the output voltage is on the order of several hundred millivolts. This can be increased by judicious selection of the semiconductor material, dimensional variations, selection of improved generator shapes and over-all configurations and the use of associated Hall-effect amplifiers.

The electrodes must be specially attached to insure proper ohmic contact, and they must be specially aligned and trimmed for minimum misalignment zero-field voltage (an output across the Hall terminals in the absence of a magnetic field). The magnetic circuit must be of specially treated material and of special construction in order to eliminate hysteresis effects and saturation of the magnetic path.

The semiconductor material, and its impurity concentration, must be carefully selected to minimize the effects of magnetoresistance—the change in internal resistance under the influence of the magnetic field. Although this effect can be used in the development of certain Hall effect devices, it should be minimized in the construction of most semiconductor rotating components in the interests of improved linearity and accuracy. Among the factors to be considered in achieving this effect are the proper axis of rotation for the Hall-effect generator and crystallographic orientation of semiconductor material.

Generators for use in the construction of semiconductor rotating components are already in production. The current ones incorporate slabs of germanium; others, in various stages of development, use other semiconductor materials such as silicon and gallium arsenide. Of particular interest in the area of Hall-effect generators is the development work in progress on semiconductor film deposition.

• **Developmental models**—Although prototypes of several semiconductor rotating components have been constructed, this line is not yet in full production. Models of the brushless motor and of several different solid-state synchros and resolvers have been assembled and have been undergoing evaluation tests for quite some time.

These tests have proven the feasibility of the semiconductor approach.

Several Hall-effect resolvers have been tested and most of the anticipated advantages have been verified. In accuracy, these units are comparable to the more precise line of wound synchros. Continuing development is aimed at matching the performance of wound components with accuracies of better than one minute of arc. ■

Launch Gear for Minuteman Keeps Pace

Autonetics reports launch and checkout equipment is fully integrated despite crash-program pressures

TO PROPERLY CARRY OUT the objectives of an R&D program, the full operational mechanization of the ground support equipment should be evaluated as well as the flight hardware.

Too often ground equipment has been a tag-along necessity, receiving too little information too late to do anything but compromise between what should be done and the calendar.

Fortunately, the *Minuteman* launch and checkout equipment, according to its contractor, Autonetics, has been very closely integrated with airborne design since the early definition stage, even though the program was on a crash basis. For this reason, although this equipment is not yet operational, requirements for the weapon system have provided the primary design criteria.

The challenge to the design engineer of providing instant retaliation and continuous operation was further sharpened by the concurrency of R&D flight test with operational fabrication.

• **Launch and checkout equipment** —The *Minuteman* launch and checkout equipment—designated as Autonetics Model C18A (G&C Field Test Set) and Model C18B (Remote Control and Readout Set)—consists of two separate consoles, each approximately four feet wide, three feet deep, and six feet high. The sole connection between the two consoles is a digital data link consisting of three pairs of twisted wires. All control, command and readout information between the airborne G&C system and the R&D launch control center, or blockhouse, passes over this link.

Some of the differences between the R&D launch equipment and the operational launch equipment should now be discussed.

From a cost reliability view, it is necessary to keep the electronics-part count at the operational silo at an absolute minimum commensurate with a high confidence factor for successful flight to the target. For this reason the C18A contains not only the minimum circuitry to command the airborne computer into its various modes and to assess the results of the computer outputs, but considerable analog equipment as well.

The primary purpose of the analog-type equipment is to provide an independent series of tests to define a satisfactory or unsatisfactory airborne G&C system. To date, these independent tests have without exception verified the go or no-go condition of the G&C system as defined by the minimal operational type tests.

In the operational silo, the Autonetics Model C53 Guidance and Control coupler houses the electronics for all test, monitor and sequencing functions directed to the G&C system. The G53 circuitry has been packaged within approximately one and one-quarter drawers of equipment.

The coupler is capable of self-test and self-fault isolation. Each plug-in drawer and all wiring and connectors can be removed and replaced during standard maintenance periods, eliminating the necessity for ever allowing a soldering iron in the silo to service the equipment.

The plug-in modules, or etched circuit boards, within three drawers of the C18A are those which were repacked into the C53 coupler. In many cases, individual circuits were improved through an intensive design review program. The circuit interface with the missile has remained unchanged.

The functions of the initial turn-on sequence and filling of the airborne computer, performed by the C18A, are van-mounted in a new console for the operational program. Various optical alignment equipment and personnel baggage are also housed in the van.

• **Operational requirements** — Before discussing the detailed design features of the launch and checkout equipment, the system requirements should be reviewed very briefly:

—Fully automatic checkout and launch sequencing functions within 30 secs. total elapsed time.

—Remote operation and readout capability from initial turn-on through launch.

—Compatible operation for laboratory, system integration, missile assembly building, sled testing and launch from either pad or silo.

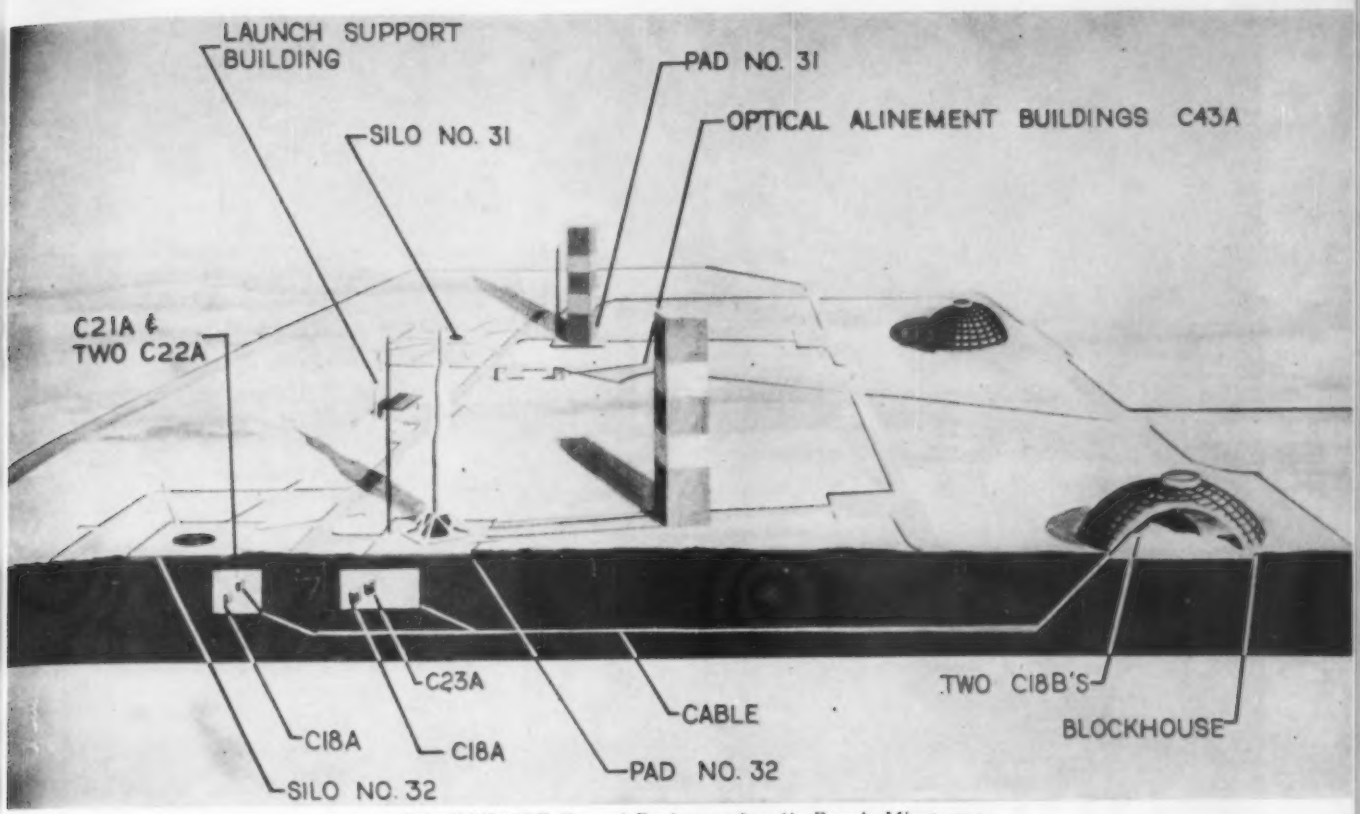
—Complete analog testing to verify operation go or no-go tests.

—The complete design philosophy for the operational hardware to be proven in R&D equipment.

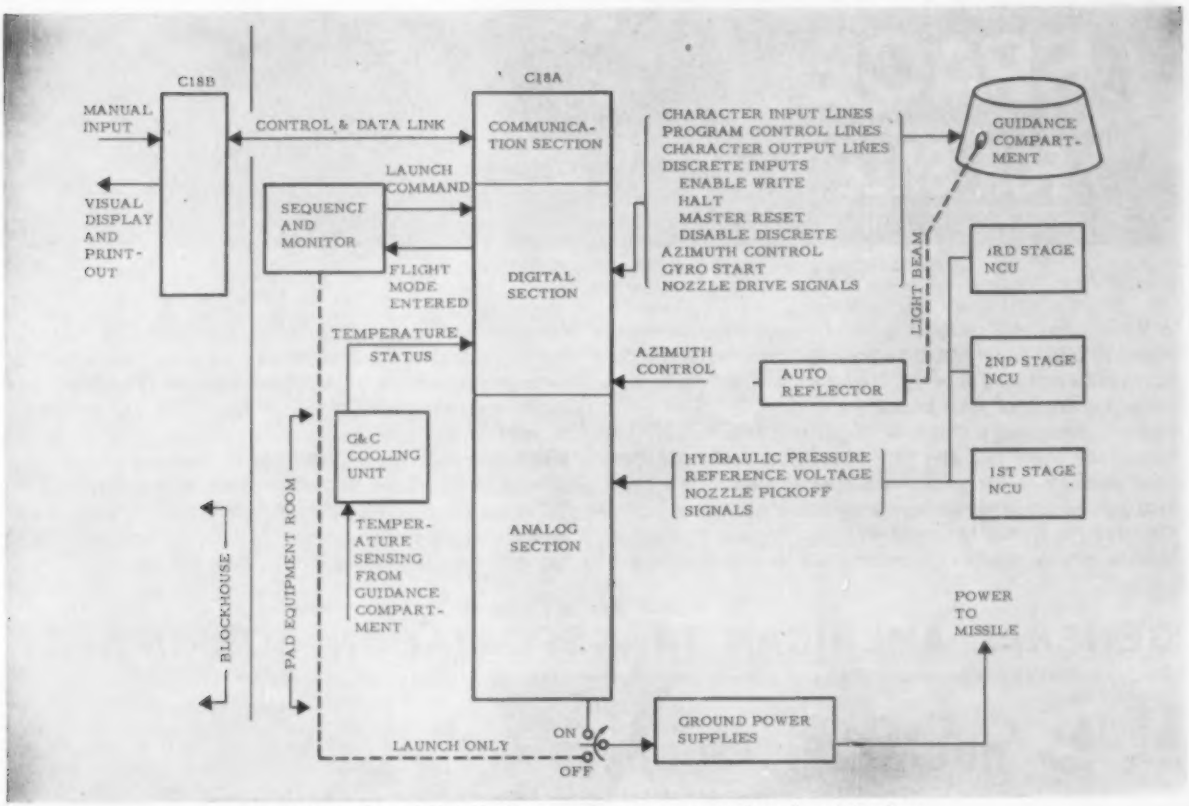
• **System operation**—All commands originate from the C18B control and readout console. The command is initiated by a pushbutton which generates a 6-bit digital word which is then transmitted in a serial fashion to the C18A G&C Field Test set. At the C18A the command code is translated into a test signal or series of test commands to the airborne G&C system. The diagram above indicates the functional interface connections between the C18A test console, the missile and certain other pieces of ground equipment.

Character input lines, consisting of six wires, are used to fill the computer memory from the tape reader and tape-reader-control electronics in the field test set. The six lines transmit four character bits, a timing bit and a parity bit, filling the computer memory with

(Continued on page 53)



LAUNCH SITE Ground Equipment for Air Force's Minuteman.



FUNCTIONAL INTERFACE diagram of Minuteman launch and checkout.

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When handling of those kilocycles begins to be a vicious cycle and data processing operations jam up like Labor Day traffic, don't just grit your teeth. There is a way to get past the roadblock of conventional magnetic recorder/reproducer limitations. That way is the all new G-100 unit produced by our Mincom Division.

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Other plus features of the G-100 include greater dynamic range, a built-in monitor switcher, and built-in calibration so that you may preadjust the recorder to the incoming signal amplitude. And don't overlook Mincom's exclusive dc tape transport. Another premium of the G-100, it gives you freedom from fear of outside power fluctuations.

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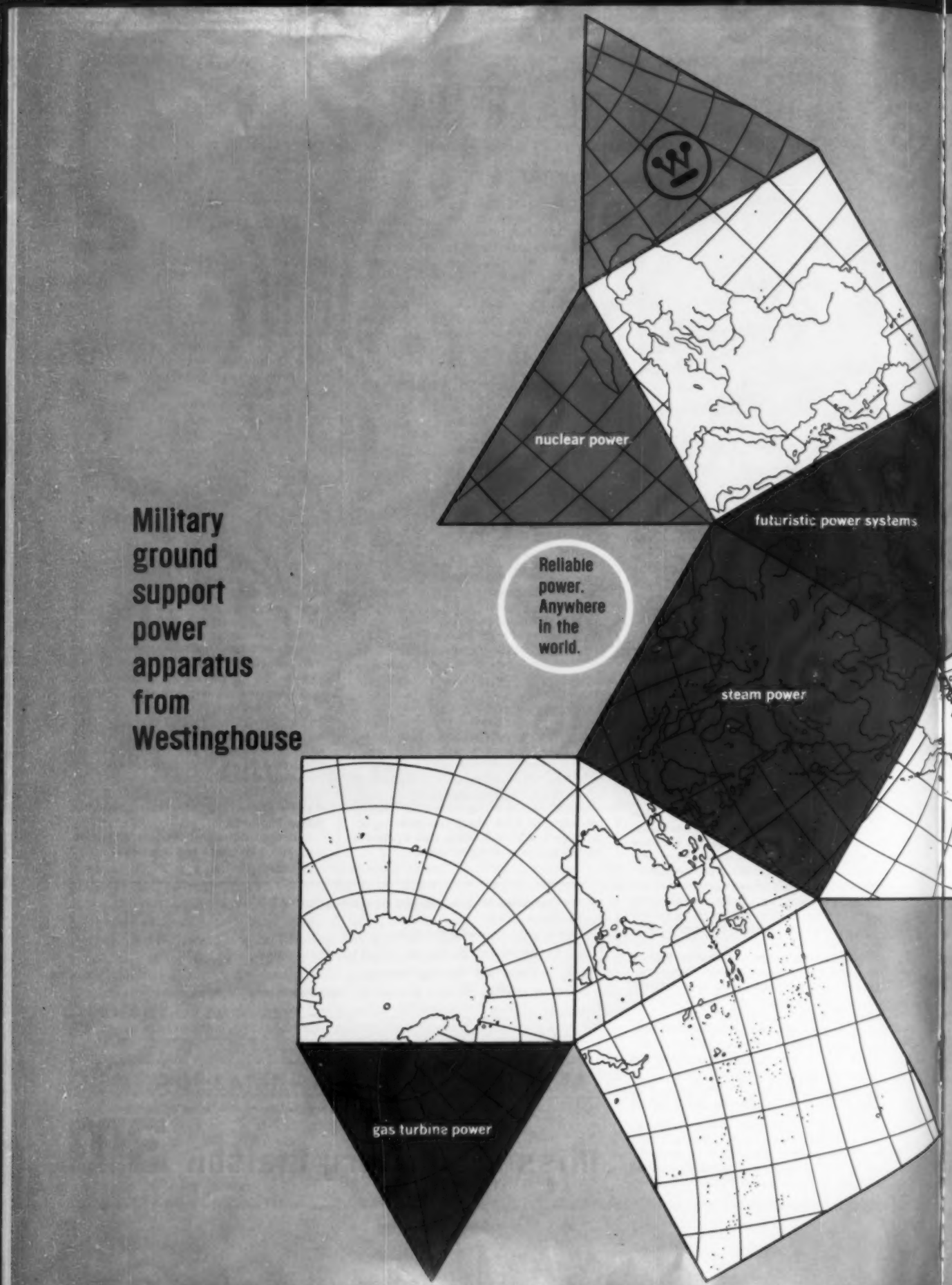
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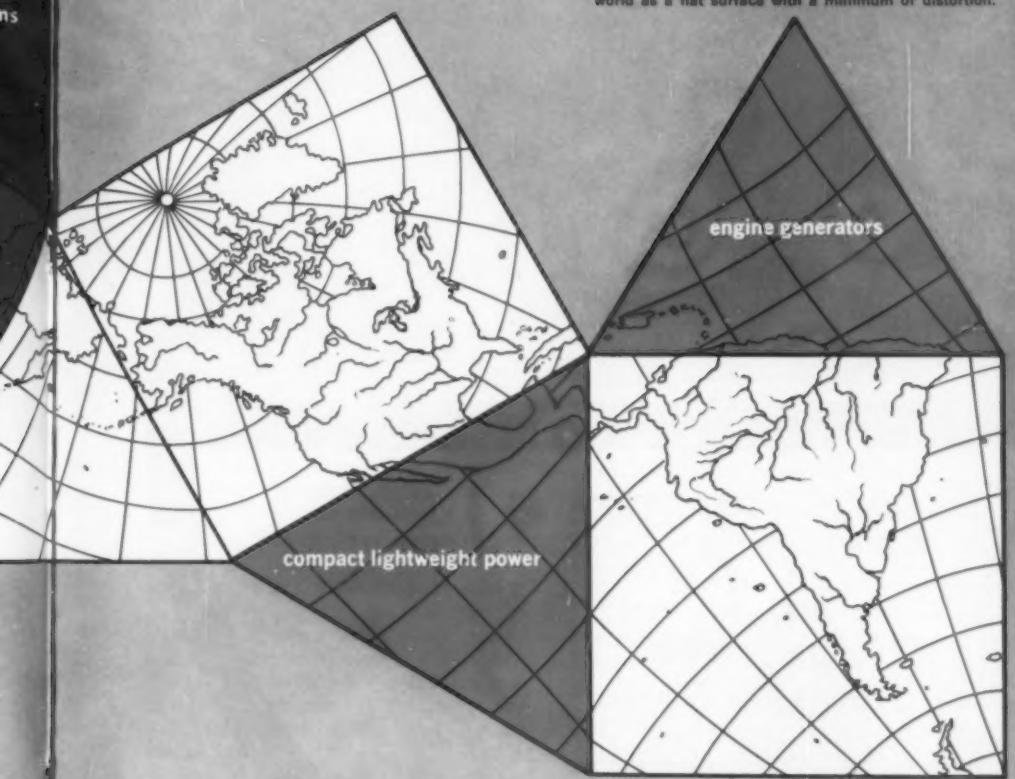
Note: Illustration is the Dymaxion projection of the globe by R. Buckminster Fuller. It depicts the spherical world as a flat surface with a minimum of distortion.



Westinghouse

This slotted-blade vaneaxial fan design represents one of many special fan models available at Electric Boat Division for applications where small size, light weight, long maintenance-free life and low structure-borne vibration are critical factors □ At lower speeds and with smaller tip diameters than conventional fans, these turbo-slot fans produce the same air flow and pressure rise by controlling the flow of air over the surface of the rotating air-foil □ Lower speeds extend the service life of the vaneaxial fan and reduce the airborne noise and structure-borne vibration levels □ Smaller tip diameters allow for light-weight design and further contribute to lower airborne noise levels □ Call New London, Conn., Hilltop 5-4321, Ext. 1933, or write Fan Dept. (MR), Electric Boat, Groton, Conn. ELECTRIC BOAT A DIVISION OF GENERAL DYNAMICS GIIIIIIIID

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(Continued from page 47)

characters in the octal number system at a rate of 200 characters per second. The computer memory, when filled, contains the ground program and flight program including launch site and target coordinates.

Four lines—called the program control lines—are used to send all commands from the ground ordering the computer to initiate given portions of its program. Commands are in the form of binary codes. Another set of lines transmits information from the computer to the ground equipment.

This set of six lines—four of which form a decimal number in binary form along with a timing signal and a parity bit—transmit two types of information to the ground on a time-shared basis. The first type consists of codes which generally indicate the status of the computer. The second type of transmission is numerical data to be printed out at the C18B readout equipment in the blockhouse.

There are certain discrete inputs to the computer which enable the ground equipment to control general modes of computer operation, such as Enable Write, Halt, Master Reset and Disable Discretes. The commands are on separate lines between the C18A and the computer.

Enable Write and Halt commands are used during the computer fill operation in such a manner as to enable the computer to write in its cold storage memory. The Master Reset command will tell the computer to halt operation and restart its operation at the beginning of its program.

The Disable Discrete function is used to insure that the discrete outputs of the computer are in the false state during the periods when power is applied to or removed from the missile. This is desirable because it is impossible to prevent the possibility of random outputs during these periods.

A 2-bit binary signal from the test set—principally a retransmission of information from the autoreflector—holds the inertial platform in the proper azimuth alignment. Also, when power is first applied to the computer guidance system, an overvoltage signal is applied to the gyro motors to quickly attain sufficient speed to enable operation of the air bearings.

The nozzle drive signals from the ground field test set are also directed to the guidance compartment since it is in this area that the nozzle signals are switched to the various stages by the computer. Both sinusoidal and step function test signals are injected into the missile at this point.

Hydraulic pressure and a reference voltage are measured on each flight control system at the beginning and end of each nozzle unit test. These voltages and pressure analogs are printed out as part of the test data on the C18B in the blockhouse.

During step function tests the nozzle deflection voltage analog is converted to a digital value and transmitted to the readout equipment. During sine checks the nozzle pickoff signals are returned to the servo analyzer.

• **Associated support equipment**—The autoreflector — located approximately 500 feet from the missile—is principally an optical instrument which transmits a chopped beam of light through a window in the guidance compartment to a mirror mounted on the platform. The return light beam is compared in phase with the transmitted one and the results of the comparison are converted to electrical signals.

These signals are then transmitted through the ground test set to the airborne computer where they cause the computer to servo the platform into alignment with the light beam. Azimuth alignment is thereby referenced to the autoreflector position.

Another piece of auxiliary equipment is the guidance cooling unit which is comprised of a refrigerator, control system and a pump circulating chilled water through the guidance compartment. The control system senses the output of a thermistor in the helium stream within the guidance compartment and controls the flow of water to maintain the compartment temperature within very close limits.

A sequencer and monitor is used during the final 30-sec. countdown and, at the beginning of this period, it sends a signal to the ground test set indicating that the 30-sec. countdown is to start. Near the end of the period the ground test set sends a signal back to the sequencer and monitor indicating that the computer has entered its flight mode. Also during this final countdown, ground power to the missile is sequenced on and off by the ground test set.

All of the control and readout facilities required to test and launch the guidance and control portion of the *Minuteman* missile are contained on the two panels of the C18B Remote Control and Readout Set. The two control panels are placed side by side with the various controls and indicators arranged in such manner that they can be conveniently operated by one or two operators.

This concept of fully automatic checkout and launch sequencing has enabled the Air Force's *Minuteman* program to gain more than a year toward its all-important operational readiness date. ⌗

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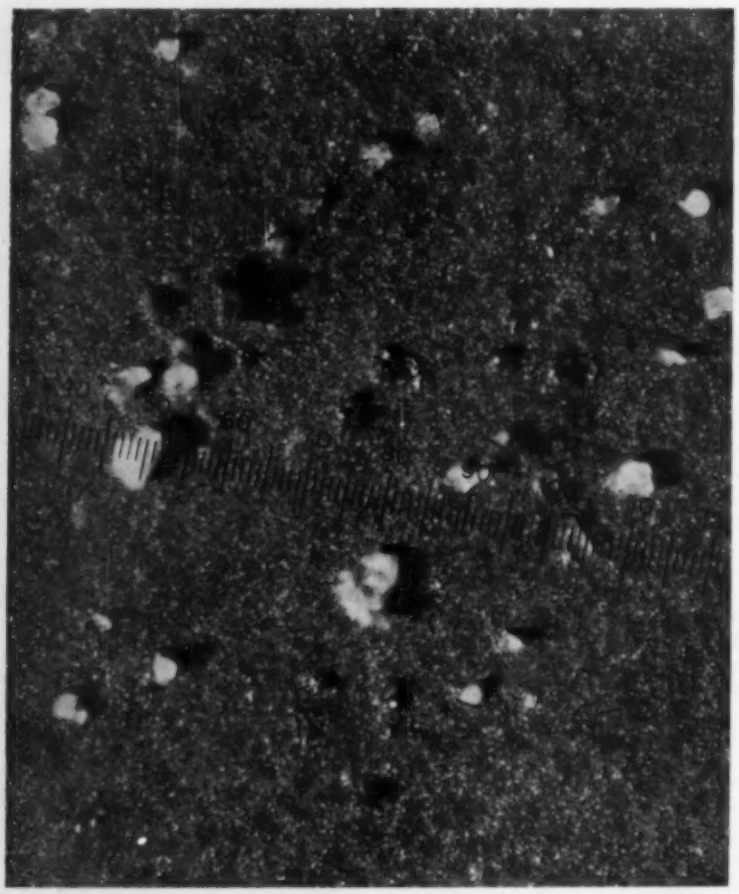
Cutting Cost of Clean Hydraulic System Parts

Vickers' work shows that new cleaning techniques, parts and materials can control contamination better, cheaper

by **A. B. Billet** *Senior Staff Engineer*
Aero Hydraulics Division
Vickers, Inc.



ACTUAL PHOTO of filter-trapped particles, magnified 100 times, shows amount of foreign material collected from one square for the particle size count.

FROM A DOLLAR standpoint, the fantastic campaign against dirt in missile hydraulic systems may be making components too clean.

It is now evident that a re-evaluation of contaminant control procedures could pay off by improving system performance for the same cost.

Without compromising the cleanliness of missile hydraulic systems, greater emphasis on the contaminant tolerance of system components will help insure maximum reliability, even though the reliability requirements have advanced to a point which was not believed practical a few years ago. A high level of system and component cleanliness has been a major factor in making successful missile flights and space shots as commonplace as they are today.

During the early part of World War II, contamination control involved little more than the simple expedient of installing filters in the hydraulic system, often of the 25 micron type. As performance requirements increased, this was rapidly changed to an industry standard of 10 micron nominal and 25 micron absolute. Now, in missiles and space vehicles, 1- and 2-micron filtration is required, with a rigid pre-system operation cleanliness requirement.

New ultrasonic cleaning techniques and high-temperature and high-pressure flushing techniques are used to obtain a high level of component and subsystem cleanliness. Final testing, evaluation and assembly is performed in special, surgically clean rooms. These environmentally controlled rooms permit extremely close control on wear environments, access of personnel, type of tools and the processing of materials. They are pressurized and air filtered to take out 1/10th micron dust particles.

• **Contamination measurement** — Accurate measurement of contaminant level is a prerequisite for effective contamination control. Approximately five years ago Vickers helped develop the visual patch standard, in which the total contaminant from pump and system filters is placed on a filter paper and visually compared to an established standard. The criterion of measurement is the amount of metal and dirt particles and the color.

A more recent development involves microscope examination of an 100 cc. sample of fluid removed from the component or system. Contaminant from this sample is placed on a membrane-type filter paper, and the actual particles of contaminant are counted and classified by size under 100X magnification. Some systems require a cleanliness level such that contaminant particles down to 5 microns must be counted. In some cases, a laboratory

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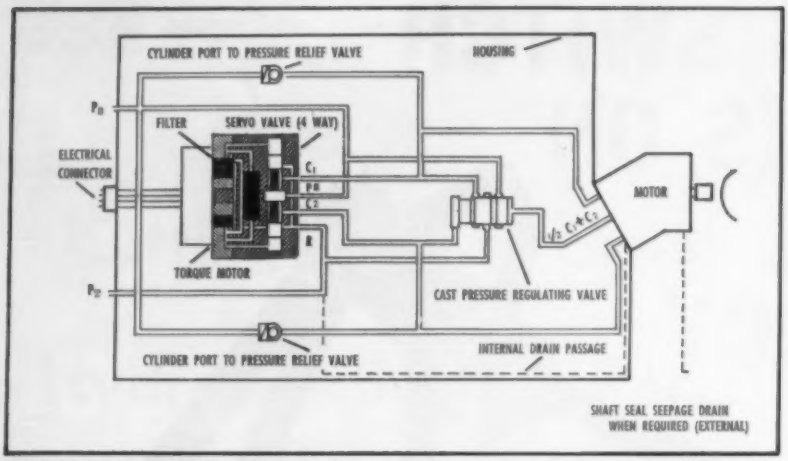


SCHEMATIC OF Vickers integrated servo-motor, which puts parts in single housing.

technician requires 4 to 5 hours to count the number of minute particles on a single patch sample.

A system and its related components are carefully cleaned and an optimum cleanliness level established before it is put into service. Once operation, begins, however, contamination is too often allowed to build up without corrective measures being taken. To insure satisfactory field operation, it is imperative that a complete and effective field contamination measuring procedure be defined at the start of a program. This procedure must be effective in the following areas:

—Measuring system contamination.

—Evaluating contamination results.

—Taking corrective action when contamination is above the maximum limit.

• **Contamination common sense**—Efforts to control and measure contamination represent a sizable investment in time and money. Although the assurance of maximum reliability warrants top priority, there is justification for asking—"Are we getting optimum results from this investment?"

Therefore, to achieve optimum results, it would seem advisable to establish several zones of cleanliness levels for a missile system and its supporting equipment—i.e., determine the most critical area and establish the rigorous contamination level required for that area. Other areas requiring less rigid control would then be determined and correspondingly lower requirements established.

The idea here would be to relax somewhat the contamination control efforts in an area with relatively low cleanliness requirements — reservoir, non-rotating parts, etc.—and transfer some of this attention and effort to the area or areas where more rigid control is required. These areas include the servo valve, where every precaution is justified, and ground support equipment where past experience shows more attention is required. Three zones—the servo valve actuator, the hydraulic pump and associated GSE—should be singled out for special attention.

The first critical part—the servo valve actuator — translates hydraulic horsepower into mechanical work and actually controls the missile flight control system. A few grains of dirt here could cause missile destruction.

It is immediately prior to this area that finer system filtration is required—specifically, one-micron filters. It is in this area that all contaminant particles, down to 5-micron size, should be inspected and counted from fluid samples.

As outlined below, considerable progress has been made in designing and building pumps that are tolerant of contamination. More attention should be given to applying this same realistic approach in the design of servo valves. Suggested steps that could be taken to improve the contamination of servo valves include:

—Further studies to determine optimum valve and spool materials.

PHOTO of integrated servo-motor package shows how eliminating lines between motor and manifold reduces contamination areas.

—Use of high force level on the servo valve output stage.

—Reduced valve spool clearance to keep out contaminants. Design studies would be required with regard to thermal coefficients and the ability to reduce binding between valve and spool.

Contamination tolerance is one of the advantages provided by a new, integrated servo-motor developed by Vickers. In this design, the servo valve, hydraulic motor and internal relief valves are incorporated in one housing as shown in the above schematic. Elimination of hydraulic lines connecting motor and valve manifold reduces the number of areas where contaminants might be trapped. Also, there are fewer fittings which might contribute to contaminant generation.

• **Hydraulic pump**—Most missile systems call for initial static cleanliness level on the pump. This may be achieved through the procedures mentioned earlier: ultrasonic cleaning, final assembly in a "white" room and high-pressure flushing. This effort can be a total loss, however, as the pump generates new contamination in the system during operation. If the pump contaminant generation level is too high, the entire hydraulic system can be quickly contaminated many times beyond its previously satisfactory limits.

At Vickers, detailed studies have been made of contamination generation in pump rotating parts, particularly bearings. As a result, changes have been made in the design of ball and roller retainers which are now available in production bearings of major manufacturers. These changes include use of new materials, improved finish and changes in the retainer dimensions which have produced bearings that generate far less contamination during operation.

Improvements have also been made in the self-aligning characteristics of bearings and in wear qualities of the pump valving surfaces. Special assembly procedures minimize the creation of metal slivers during the mating of parts. Incidentally, use of these special assembly fixtures and bearing heating procedures that make it possible to drop all bearings and spacers on the drive shaft in one operation, eliminates hours from the assembly operation.

Speaking generally, it is useless to obtain an initial static cleanliness level in the system finer than the total system generation level after 10 minutes of operation. If this level is not acceptable from an operational standpoint, then the pump generation level must be reduced accordingly.

Development of the contaminant minimum pump has been paralleled by development of the contaminant tolerant pump. For some systems where con-

tamination is known to exist, certain features can be designed into the pump to make it less susceptible to contamination. The Vickers approach to the problem includes various dimensional changes to alter tolerances, the use of ductile iron in the cylinder block and bearing ball retainers, and the use of tungsten carbide plating on mating valve plate surfaces.

It's interesting to note that the contaminant tolerant design, is also, in effect, a contaminant minimum design because it generates very little contamination in its operation. High-hardness materials and well-matched parts minimize generation of wear particles.

• **Ground and static equipment**—This zone would include non-rotating, or non-moving, hydraulic components within the vehicle proper, such as reservoir(s), check valves and accumulators. The cleanliness level of this zone can be lower than that for the other two systems, since two or more filters are used between these components and the final servo control zone. Once the cleanliness level is established for this equipment, however, it must be rigidly maintained.

Ground support equipment warrants much greater attention than it has received up to now. In the past, much of this equipment has included commercial components not intended for critical cleanliness applications. Heavy and continuous contamination has resulted from the use of standard iron pipe, pipe thread compound and castings that were not pre-cleaned. Unfortunately, even the best filters are not efficient enough to fully protect the missile system in such cases.

It is necessary to have a continuous-field contamination check with procedures that will insure frequent and adequate inspections. In a recent study of contamination problems that developed in the field operation of a military system, it was determined that many repeated failures of hydraulic components in the vehicle were due to failure to obtain an adequate cleanliness level following each previous failure.

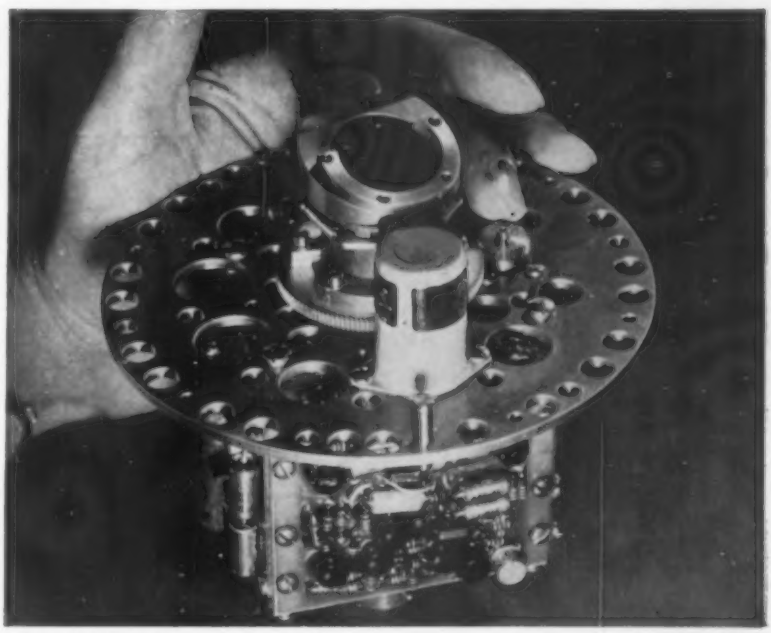
A further inspection of the ground support hydraulic flushing test stand indicated that the filter had not been changed in two years. As a result, the pressure drop became so great through the filter that it had caused complete failure of the filter element. Thus, instead of being a ground means for obtaining a cleaner system, the flushing stand was heavily contaminating the airborne system each time it was used.

Careful planning is required, therefore, in the early stages of GSE design and development. Steel tubing should be used rather than iron pipe, and ultrasonic cleaning specified on many of the more critical components. ¤

Bristol choppers help first U.S. Astronaut maneuver space capsule

Four Bristol Syncroverter* choppers formed a vital part of the infrared horizon sensors manufactured by Barnes Engineering Company, Stamford, Conn., and carried aloft in NASA's MERCURY capsule by the first U.S. astronaut to reach outer space.

The Bristol choppers function as sensitive phase detectors in the sensors as they establish a horizontal reference plane for the vehicle.



Infrared Horizon Sensor undergoes rigorous optical, mechanical, and electrical checks at Barnes Engineering Co. One Bristol chopper is located in foreground, in front of gear.

Bristol Syncroverter* choppers, noted for low noise, long life and high reliability, are finding a vital place in more and more missile guidance systems, as well as in analog computers, d-c amplifiers, and test equipment for industrial applications. More than 200 models available. Write for complete details.

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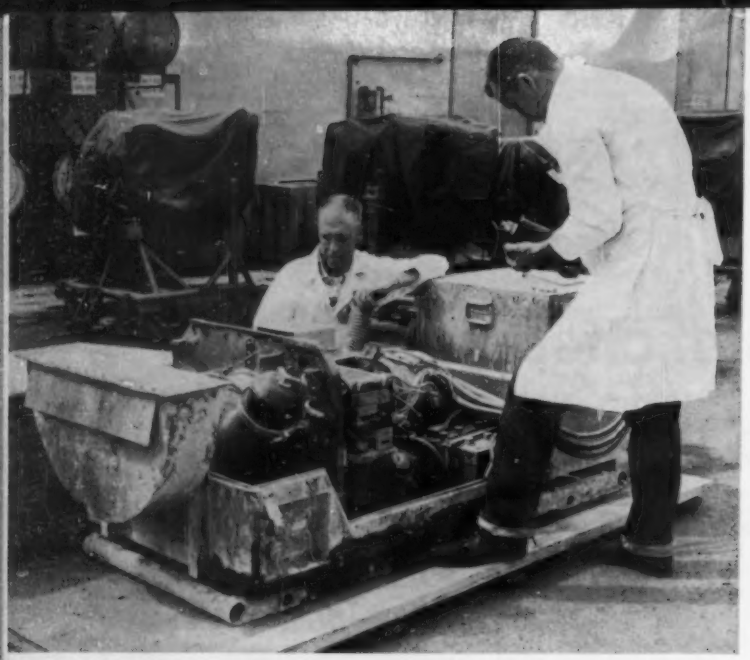
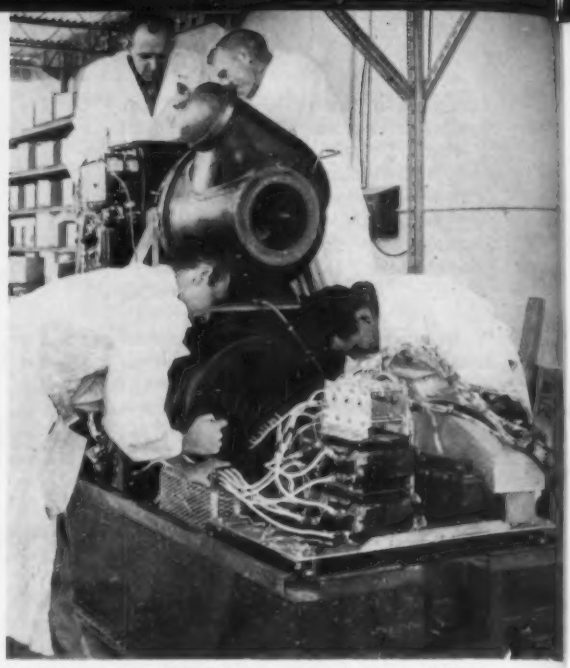


CONDITION of a typical Sergeant missile turbine generator set sent back from field use. Units are in production at AiResearch-Phoenix.



TECHNICIANS CHECK gas turbine slated for delivery to Army for use in Jupiter support.

GSE MISSILES

Gas Turbine Ideal for Field Support

Experience with Jupiter, Sergeant shows merits of small size, light weight, speed for mobile missile systems

RULE OUT minimum size and weight considerations or choose small gas turbine engines for auxiliary power. This basic choice became readily apparent during the development of early tactical missile support systems.

Aside from envelope-weight considerations, its warmup characteristics alone single out the turbine. Swift timing—a prime requirement for tactical mobility—is cancelled by typical reciprocating engine starting and warmup requirements. A turbine's average 15 to 60 seconds from start to load even at temperature extremes of −65°F is exactly tailored to such requirements.

• **Turbine history**—Turbines—powering such proven, operational systems as the Army's *Sergeant* and the Army-Air Force *Jupiter* and upcoming on the Army's *Pershing* missile—have already established the logic of auxiliary power turbines for mobile field support requirements.

As a background to the small gas turbine in its missile support role, it is interesting to note that the first successful small gas turbine was not developed until 1946. From this turbine came the first pneumatic starter—the now-almost-standard method for converting pneumatic power to mechanical power through an air turbine starter.

In the missile support field, AiResearch division of the Garrett Corp. began work with the Army in 1957 on the *Redstone* missile. The turbine concept was sold to the Army—only to have its order canceled by termination of development funds. Next came the *Jupiter*. However, only with the *Sergeant* did turbines really get an opportunity to prove themselves both tactically and logistically.

A spare turbine for each *Sergeant* system was initially planned. However, as the turbines gained test time in the program, this requirement was dropped. And, after long and careful evaluation, AiResearch turbines were chosen for the *Sergeant* because of their performance, reliability and growth potential.

• **Jupiter-Sergeant experience**—The first actual hardware experience with ground support of a liquid-propellant missile came with the *Jupiter*. With only five months lead-time, a turbine-driven power package to Army specifications was built and delivered. This unit produced 100k of 60cps a-c power in a 3000-lb., self-contained, skid-mounted package.

Heart of the *Jupiter* support unit is a 315-lb. turbine producing 225 hp to drive a 1200-lb. alternator. The support unit was designed from modified off-the-shelf equipment and met all the Army requirements for reliability, mobility and cold-weather operation.

While the *Jupiter* turbine unit met all specifications, its addition to the missile system came late in the system design stage. Therefore, the first instance of a missile system completely designed to take advantage of the small gas turbine was the solid-propellant *Sergeant*

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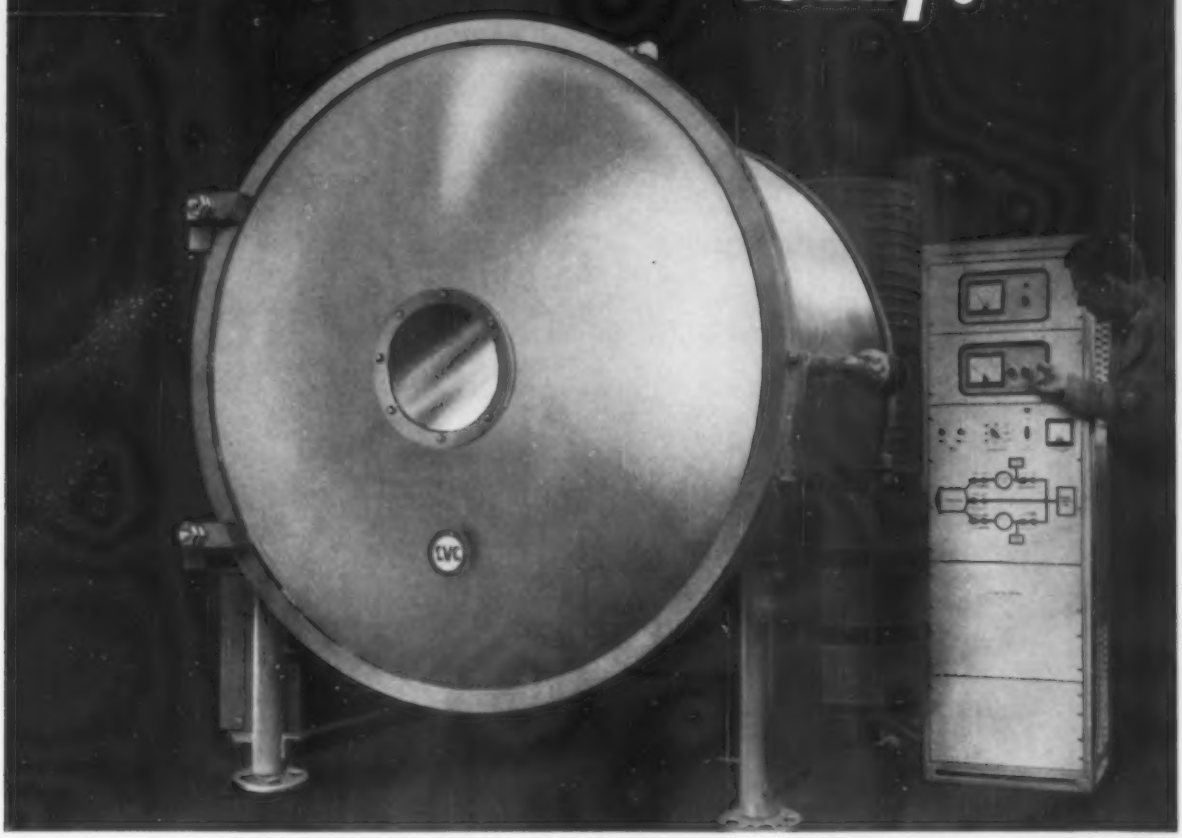

Within this giant chamber entire satellites can experience the extreme thermal environments of outer space.

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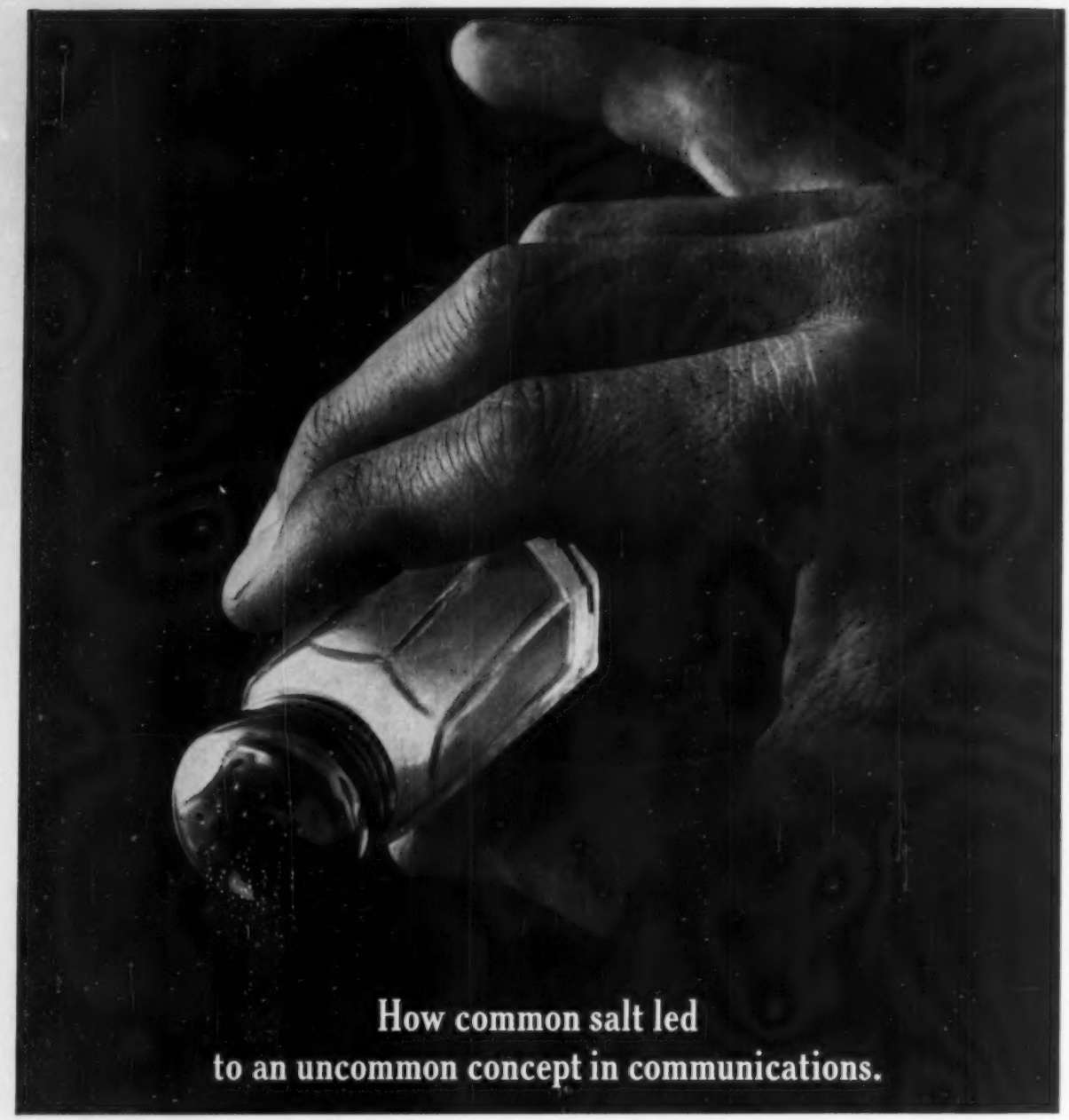


How common salt led to an uncommon concept in communications.

An unusual new device to increase radio reflectivity, now under development at Northrop's Radioplane Division, may well revolutionize the field of space communications. Called ADSAT (for Anomalous Dispersion Spherical Array Target), it should extend the usefulness of passive communications satellites out to 22,000 miles—the 24-hour orbit.

The germ of the ADSAT idea actually came from early X-ray diffraction experiments with ordinary salt crystals which yielded a pattern of intense bright and dark spots. This hint of resonance with the crystal lattice led Northrop researchers to attempt to duplicate this effect at radio frequencies—and the first version of ADSAT looked much like a molecular model, with silver-coated ping-pong balls serving as "atoms." The size of the balls and the intervals between them were carefully calculated to resonate with and reinforce the incoming frequencies.

In its present, basic form, the ADSAT satellite is a collapsible, spherical network, 100 to 400 feet across, with the resonant balls at each intersection of the network. It is designed to be launched in a small package, and inflated in orbit, much like Echo. The reflected signal, however, can be 1,000 times as strong as that obtained from a simple, Echo-type target of equal size.

The development of the ADSAT concept demonstrates once again Northrop's unique ability to visualize problems in space technology, decide what should be done, and come up with solid, workable answers.

RADIOPLANE
A DIVISION OF
NORTHROP

—developed for the Army by JPL and Sperry-Utah.

In this system, by installing turbines on the transporter-erector-launcher and on the guidance vans, it was possible to eliminate three standard 2½-ton trucks which would otherwise have each towed a trailer-mounted, engine-driven generator set.

• **Disadvantages overcome** — with the operational *Sergeant* system, two most often cited turbine disadvantages —noise and fuel consumption—have been put into proper perspective. In an enclosed, attenuated package roughly one-quarter the size and one-eighth the weight, turbine noise levels on the *Sergeant* are less than that of standard Army engine generator sets. As to the second turbine problem, average fuel consumption in a typical *Sergeant* launching has proved to be six to seven gallons total—hardly a serious logistics problem.

Granting the diesel a 2-to-1 advantage in lower fuel consumption over present turbines, the chart above shows that over 48 hours of turbine operation are required before the transport weight, including fuel, cancels out the turbine's initial weight advantage. In addition, the turbines burn the same combat gasoline used by their transporting vehicles.

The *Sergeant* missile support GTG (gas turbine generator) is basically a shaft power unit similar to a standard unit. Its output is available through a generator as 400-cycle alternating current—some of which is rectified to give d-c power.

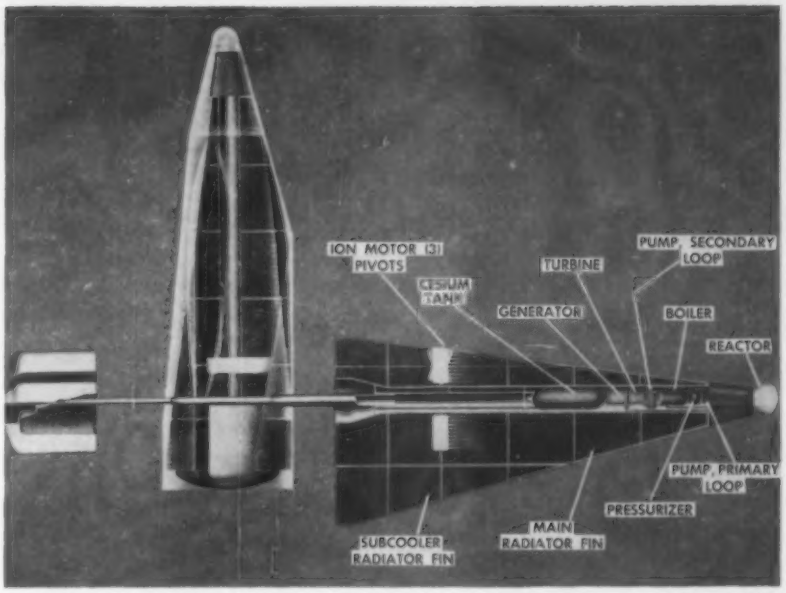
In the *Sergeant* system, two of these units are used. One is mounted on, and powers, the TEL's electrical and hydraulic system. The second turbine supplies current to the electronic guidance van. Removing and replacing either unit is quickly accomplished with the entire enclosure serving as its own shipping container. As many as four enclosed turbines with 3-4 hours of fuel each can be readily transported as slung-load under a helicopter.

Many details of the Army's latest tactical missile system—*Pershing*—are still classified. However, in this system, the Army has again turned to small gas turbines in a much improved and refined *Redstone*-type system. The 2600-lb. *Pershing* turbine power package is capable of producing electricity with two different output characteristics and includes a 3000-psi air compressor and an air conditioning unit.

• **Future developments** — The turbine-powered support packages of the near future are indicated by recent developments in electrical power generation. For example, a 30-hp small gas turbine—currently being demonstrated by AiResearch—directly drives a generator employing silicone-controlled rectifiers. The development for the first time frees the turbine from size, weight and reliability restrictions imposed by the necessity of gearing normal high turbine rotational speed to match generators designed for low reciprocating engine speeds.

The rectifiers allow "pieces" of the 3200-cycle high-frequency electricity generated to be "fitted" together into usable 60- or 400-cycle current. Based on this development an enclosed, turbine-driven generator set is being produced which will be capable of producing 100kw of 60- or 400-cycle electricity. The complete high-frequency set will weigh only about 800 lbs.

Another development—a turbine-driven standard generator set—is now being built for the Army. Featuring flexible, two-piece construction, the set includes a bottom, skid-base enclosure containing a 60-gallon fuel tank, pump and filter, a tool box and drag bar. A second enclosure, mounted on top of



SPACE CAPABILITY of turbines is highlighted by AiResearch work on AF's SPUR.

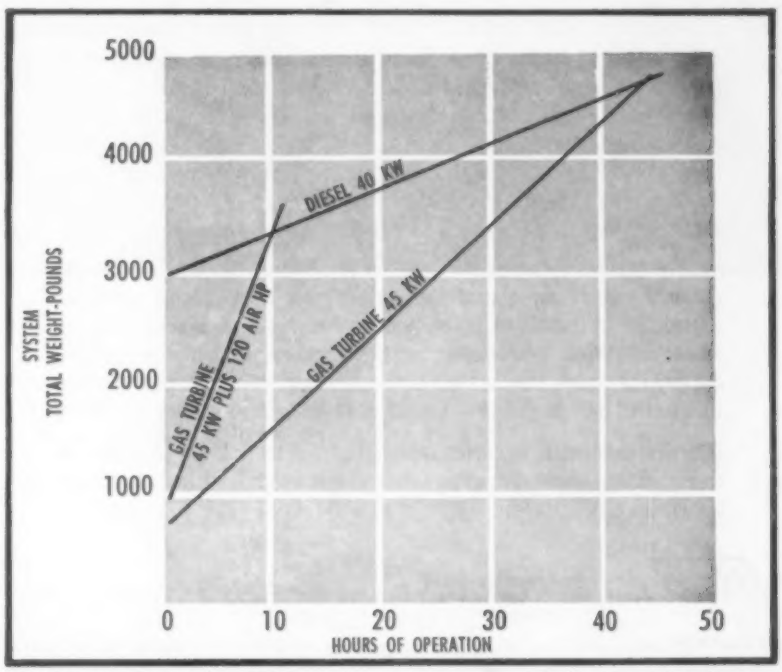
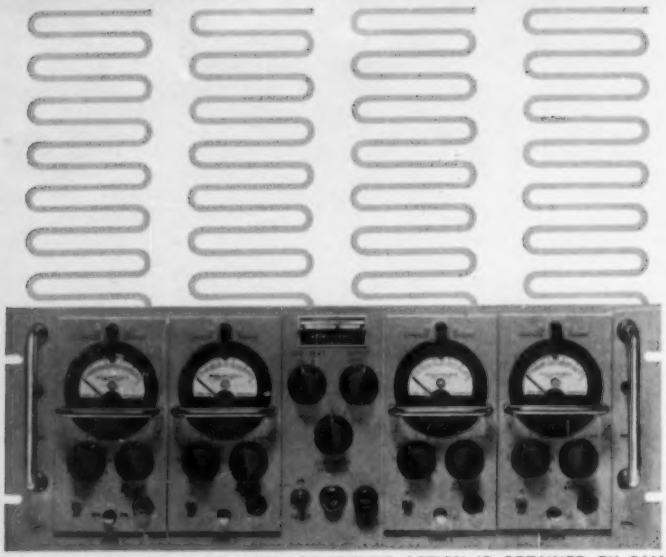


CHART SHOWS it takes 48 hours of operation to cancel turbine's weight advantage.



DCA-1000A DIVERSITY COMBINER. COMBINING ACTION IS OBTAINED BY SAMPLING NOISE OUTPUT OF EACH RECEIVER BY MEANS OF HIGH-PASS FILTERS.

POSITIVE DATA RETRIEVAL

...telemetry data from up to four sources combined into one improved output. The DCA-1000A Diversity Combiner is designed to handle FM/FM and PDM/FM signals in ground support installations in which up to four receivers with 500 kc and 100 kc bandwidths receive the same RF transmission simultaneously. Signals of the receivers are mixed by combiner into one improved output. The s/n ratio is better than that of any one of equal input, or as good as the best single input. Unit responds instantly to rapid changes in s/n ratio.

Fail-safe circuits assure signal reception at all times. One circuit per input prevents loss of any one of the input signals from causing additional degradation of the output signal. Another circuit guards against complete loss of data should the combiner fail. Each channel has its own plug-in unit, and any one module may be removed for servicing while the others continue to operate. Unit is designed for standard 19-inch relay rack mounting.

Diversity Combiners for non-standard signal reception are available on special order. Where the utmost in exacting communications equipment performance is demanded — Vitro is at work.

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the first and easily removable from the lower section, contains a small gas turbine, a generator, electrical equipment, instruments and other equipment.

With both enclosures assembled, the 750-lb. unit comprises a self-sufficient mobile power set readily transported by air or any standard vehicle. When the bottom enclosure is removed, the turbine easily mounts on a launcher or guidance vans for applications such as the *Sergeant* system.

• **Space applications**—Since it is an air-breathing piece of equipment, the future of the turbine might seem limited to ground applications. However, in the face of a rapidly developing space technology, the turbine has kept pace. Specifically, AiResearch is the prime contractor and systems manager for the Air Force's *SPUR* project (Space Power Unit, Reactor). Designed for space probes in the latter part of this decade, *SPUR* will initially furnish 300 kw—later increase to 1000 kw—at a weight of 8 lbs. per kilowatt.

Gas turbines, then, are approaching the point where their cost of operation will prove as low or lower than comparable reciprocating support equipment. The big factors in this low-cost operation will prove to be much lower maintenance costs for turbines and high reliability—factors considered important in the design of anybody's support system. ¤

Burroughs Making New NORAD Command System

A NEW COMMAND and control system—designated the 425-L—is being produced and installed for North American Air Defense Command headquarters by Burroughs Corp.

The new system will collect, process and display air defense intelligence from all Air Force warning and communications networks. Overall system management will be exercised for the AF by the MITRE Corp.—a non-profit organization providing systems engineering and technical direction for the Air Force's Electronics Division.

Although similar to the Burroughs 5000 series computer, the new command and control system is expected to use a Modular Data Processor, D825, which in turn uses thin film rather than magnetic-drum memory circuits. The main advantage of the D825 is that each computer schedules itself and initiates master/slave relationships with the other computers in the system as required for optimum parallel operation. High computational capacity is obtained by using all system elements continuously while balancing the arithmetic, memory and input-output modules. ¤

NEW NAVY... NEW WEAPONS

New naval defense concepts are vital in these days of nuclear submarines and guided missiles. One of these: A destroyer-class hydrofoil boat guided to lurking enemy submarines by remote sonobuoys. Ford Instrument is now working to turn this new concept into operational hardware . . . one of the most recent efforts in our 46 years of service to all branches of the armed forces.

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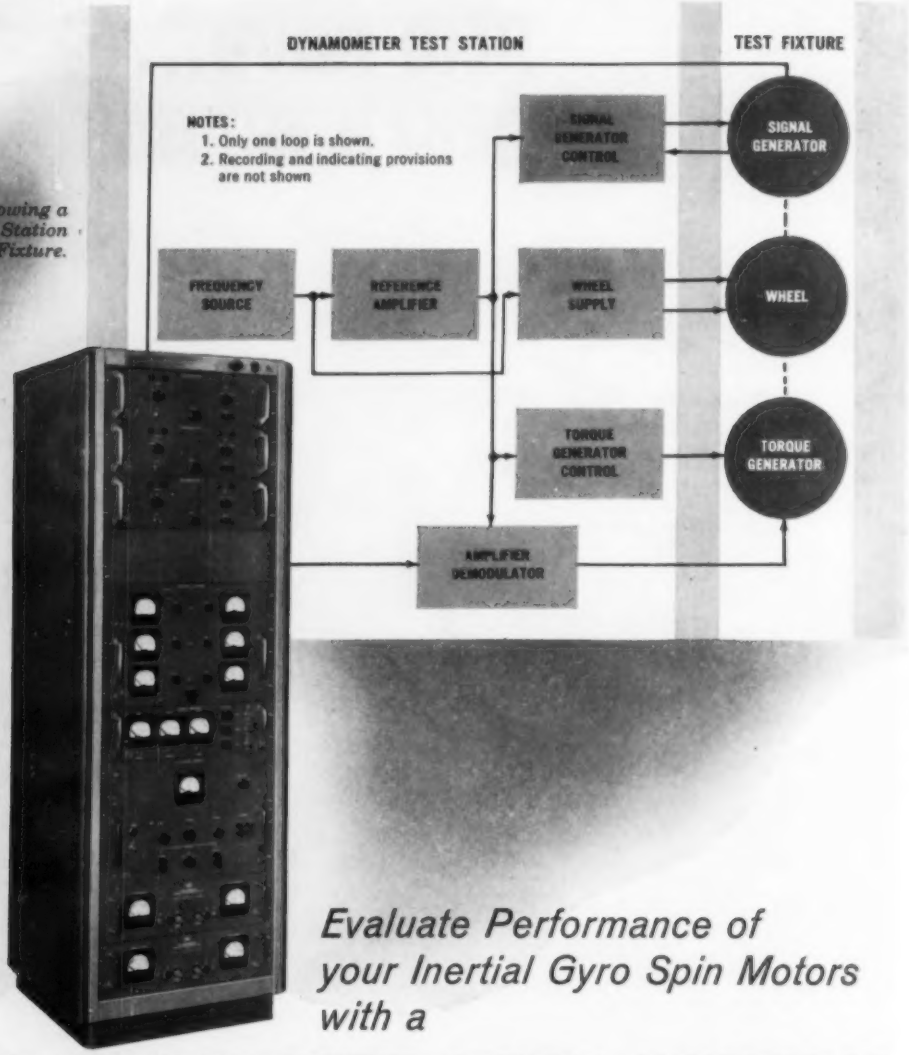

Typical system showing a Dunn Dynamometer Test Station with a Test Fixture.

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DUNN DYNAMOMETER TEST STATION

Now measure bearing torque of inertial gyro spin motors . . . with the new Dynamometer test station engineered by Dunn. The Dunn T1150 Dynamometer can be used for laboratory, development or production testing, as well as receiving inspection.

Designed and built originally for the M.I.T. Instrumentation Laboratory to test 25 IRIG wheels, the Dunn T1150 controls three test fixtures independently.

The gyro wheel is mounted in a single test fixture incorporating a signal generator and a torque generator. These microsyn transducers operate in a closed-loop, torque-nulling servo system. You get complete servo electronics . . . Dunn has incorporated provisions for visual and/or graphic recording of transducer signals.

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Technical Countdown

PROPULSION

High-Temp Nozzle Process Perfected

Engineers at R. E. Darling Co. turned out an experimental nozzle that raised a number of eyebrows at a Navy West Coast testing lab recently. The firm's thermal-pressure molding process fabricates modified asbestos/resin components with densities between 1.94 and 2. Firings with the nozzles at maximum temperatures for 60 seconds resulted in no measurable char or erosion. The process can be used to fabricate complete motor cases, integral aft closures with nozzles or any other moldable configuration. The process controls long fiber alignment and achieves a shingle effect through the nozzle shape. There is no inherent size limitation.

Accurate Low-Thrust Gaging Possible

Rocketdyne has just delivered a 2.5-ton extrasensitive thrust measurement system to Air Force Systems Command at Wright-Patterson AFB. Designed to measure very accurately the thrust of ion and other electrical propulsion systems, it will be used in a vacuum test chamber. It employs a pendulum suspension to support an engine up to 27 cu. ft. in size and 200 lbs. in weight. Any specified micrometric range is measurable to 10 lbs., the NAA division says.

Liquid Propellant Sampler Developed

A dynamic-flow sampling wedge developed for use in Air Force liquid-propellant loading systems offers accuracies to within 2.5%. It was designed by Wyle Laboratories for prediction of mainstream contaminant levels over extreme density variation ranges. It also permits sampling of high-pressure flows. Sampling is by a "slice" specimen through full vertical cross-section of a stream to eliminate errors due to settling.

ADVANCED MATERIALS

Saturn Bulkhead Electro-formed

Electrical discharge forming may provide single-piece, 200-inch fuel tank bulkheads for *Saturn*- and *Nova*-type vehicles. The process, akin to explosive forming, it being researched at NASA's Marshall Space Flight Center. A 7-ft.-diameter unit using a 240,000-joule capacitor bank is being readied for detailed investigations.

Tin Can Impactors Evaluated

Soft lunar landings may utilize the energy-absorbing qualities inherent in crushing metal cones and cylinders. General Electric scientists will spend the next year studying the phenomena. The GE Missile and Space Vehicle Department experts have found that energy is distributed in a precise manner which causes a pattern of crumpling.

CBS Studies New Alloy Process

A process for automated production of semiconductor devices using an electron beam shows promise, says CBS Laboratories. Now one year old, the studies are being performed under Army Signal Corps contract. So far, aluminum silicon junctions have been formed with both electron and ion beams in the fabrication of microjunction diodes. CBS says tin, silver, and gold also can be alloyed onto silicon surfaces. A planar transistor will be fabricated next.

ELECTRONICS

Mosaic Guidance For the Future?

Present-day celestial-supervised navigation systems may be replaced for future interplanetary missions by "mosaic" guidance, says Eugene F. Lally of Jet Propulsion Laboratory. Using multiple detectors, such a system would obviate the need for continuous in-flight reference-axis updating through torquing methods. Reference-axis orientation would be maintained by an onboard computer, thus also eliminating the need for inertial platform, with its inherent drift problems. System accuracy would be comparable to accuracy of known star positions.

Transit-SNAP Union Praised

Use of higher-powered SNAP (Systems for Nuclear Auxiliary Power) units for operational *Transit* satellites may now be assured—thanks to current success of the 4.6-lb. test system powering transmitters in *Transit IV-A*. Employing direct conversion of heat generated by spontaneous decay of plutonium-238 fuel, the 5 x 5.5-in. can is providing a continuous output of 2.7 watts, the Atomic Energy Commission says. Built by Martin for AEC, the unit has supplied over 5100 watt-hours of energy to date.

Sophisticated Guidance in Tiny Missile

Redeye, infrared-guided ground-to-air missile for the foot soldier, apparently totes a lot of guidance in a small package. Reportedly, the 4.3-ft., 20-lb. missile can not only chase and hit a strafing jet fighter, but also, when fired laterally, lead an aircraft sufficiently to effect a collision course. Also, a new control approach is used, employing two opposing steering fins in the forward section, says its developer, General Dynamics/Pomona. Canted at a 15-degree angle, fins snap in and out as missile revolves. Amount of turn correction is determined by time of extension.

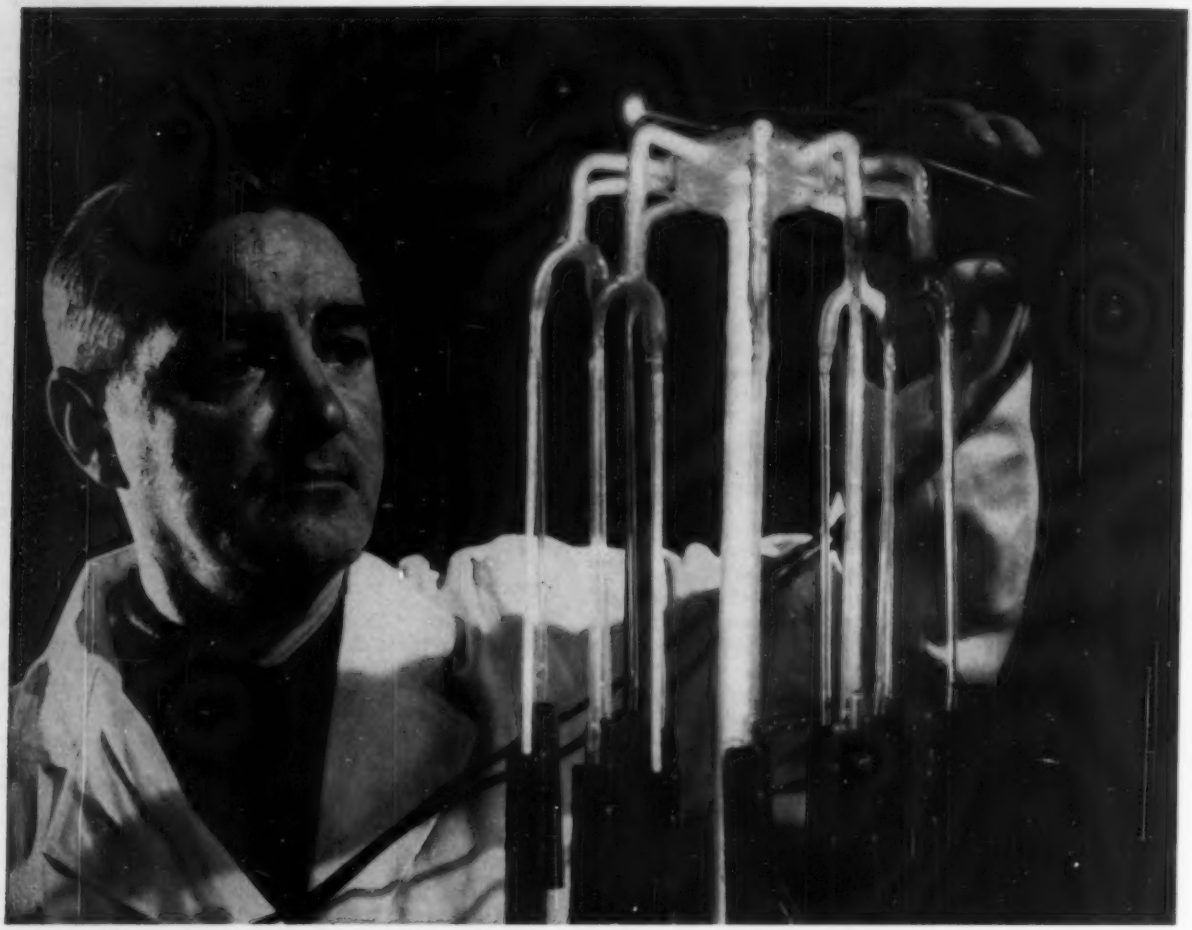
SUPPORT EQUIPMENT

ATLAS May Surpass STRETCH

An International Business Machines report indicating that its vaunted super computer, STRETCH, has failed to meet cost and performance expectations leaves the field wide open. Only existing comparable system (size and speed) is the Ferranti-produced Atlas—priced about $6-8.5 million—designed by Manchester University. The IBM system originally was expected to cost around $13 million, but price soared out of reach during development.

Data Transmission Advanced

A method for transmitting data over regular land lines at rates up to 15,000 words/minute has been described by General Dynamics/Electronics in Rochester, N.Y. A new phase-modulation technique, called DEFT (Dynamic Error-Free Transmission), is used wherein alphanumeric characters are coded into phase relationships among tones which are transmitted simultaneously. Developers say the system is virtually error-proof and jam-proof.



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RCA's APATS

(Continued from page 33)

men. This signal, at a frequency between 2200 and 2300 mc, is coupled to a wide-band preselector and a narrow-band preselector trough a power divider.

The wide-band preselector selects a 24-kc spectrum which is fed to the frequency counter and spectrum analyzer for evaluation of frequency accuracy and deviation. The narrow-band preselector, with a bandwidth of 800 kc, selects only the desired signal spectrum. The selected signal is then coupled to another crystal detector for power monitoring and to a superheterodyne receiver where the video signal is extracted.

The video signal is then fed to a high-speed magnetic tape, where it is stored for later and thorough evaluation. The video signal is coupled also to a heterodyne discriminator, where the PAM is extracted. The PAM signal is routed to the PAM console, where channel separation and monitoring is performed.

The PAM console accepts PAM pulse-train signals from the specimen through the telemetry console and demultiplexes them for measurement. Operation of this console is controlled by a programer which is part of the console.

The console is a visual/digital display and simultaneously records the measurement results of the channel selected by the programer on punched-paper tape and on a decimal printer. This operation is performed sequentially for each channel selected by the programer.

The PAM console also continuously monitors 11 manually preselected channels simultaneously. Each output of 10 of these channels is displayed on an individual d-c voltmeter. The remaining channel monitors the r-f data link PAM verify signal which is routed to the telemetry console.

The only external commands required by the PAM console are those for "start" and "stop." These commands can originate either from the programer console or from an associated remote-control unit.

A portable unit containing a receiver is used to further enhance the reliability of data acquisition from the payload by providing an alternate channel for the reception of telemetered data.

• **Power distribution**—The power distribution console accepts two feeders from commercial power lines: 208/120 volt a-c, 3-phase, 60-cycle, 4-wire, wye connected. Each feeder will be capable of transmitting a maximum of 100 amperes to the console. Each phase will be monitored for voltage and current.

Power is routed to a circuit breaker panel and then to the running-time meter panel. The accumulative running-time meters monitor the on-time of the 12-30 ampere, 3-phase power lines. The power is then distributed to the test consoles and to a low-speed data and plotting system. Metering and controls are provided to monitor and control power to the consoles and the 120-v a-c single-phase outlets. ¤

Mariner GSE

(Continued from page 37)

shaker will first check the systems at 40 cycles and high amplitude along the three axes, then repeat tests on a 28,000-lb. dynamic shaker at higher frequencies.

During Phase 8 a unique test stand, designed to check operation of extensible arms and booms in a minimum-gravity environment, will be used for the first time. These mechanisms are designed for zero-gravity operation; their operating force is just enough to overcome friction at hinge points and joints. Therefore, the test stand has been designed along the lines of a large welding positioner which can orient *Mariner* to a position negating the effect of gravity on a particular arm or boom under test.

By now the *Mariner* spacecraft is almost ready for delivery. Therefore, Phase 9 is a dummy run in which the spacecraft will be held vertically on an adapter simulating the mating structure of *Centaur*. Electrical access will be confined to the umbilical cable and the telemetry link. JPL technicians will conduct a standard countdown to check both the countdown and adequacy of the equipment. The squibs will be fired one time during the dummy run.

A Compatibility Check (Phase 10) will be made at General Dynamics' Sycamore Canyon facility by setting the *Mariner* on a dummy *Centaur*. All the items will be checked—right down to the firing switch. Here propellants and pressurization gases will be loaded for compatibility checks that were too hazardous for the JPL facilities.

• **After delivery**—Phase 11 starts after *Mariner* is delivered to Cape Canaveral. JPL personnel will run through a systems test sequence again, closely repeating the last systems exercise.

The last of the test series using *Mariner* GSE—Phase 12—is called J-FAC, Joint Flight Acceptance Component Testing. This is the final systems test before the *Mariner* vehicle is mated to the operational *Centaur* on the launch stand.

Two complete sets of GSE checkout equipment will be assembled. One will be maintained at JPL's Pasadena, Calif. facility; the other at Cape Canaveral for launch operations. Estimated cost of *Mariner* GSE is currently set at about one-fourth the vehicle cost. ¤

Azimuth Alignment

(Continued from page 24)

tional problems—the first of which is the weight of the vehicle. The dry weight of the vehicle is in the order of millions of pounds, and after the fuel is loaded, the vehicle weighs in the order of tens of millions of pounds.

The vehicle gantry is also of tremendous weight and, when the gantry is moved away from the launch area, the earth actually settles. As the fuel is loaded aboard the vehicle, depending on the underlying formation, bending, tipping or other motions can occur.

Cryogenic propellants actually shorten the missile in length as the cold liquid is loaded aboard. And the amount of shortening or twisting is not predictable.

Twist and torsion of this nature can cause the prism located on the platform to become vignetted by the window. Of course, it is really not important what gyrations the vehicle undergoes as long as the platform reference prism during the alignment remains in the collimated beam.

However, to diminish the chances of losing the azimuth reference signal, it is possible to either increase the aperture of the reflector prism or increase the aperture of the theodolite which determines the cross sectional area of the collimated beam of light.

Either or both of these precautions will increase the amount of permissable lateral displacement of the theodolite or the vehicle without losing azimuth transfer capabilities. A third way of increasing alignment capability is to translate the entire theodolite laterally in accordance with vehicle sway by the use of an automatic tracking device.

However, if the vehicle perturbations are extreme—and again it is impossible to predict just what these motions will be—the collimated beam of light may be completely vignetted by the window in the vehicle. This possibility is illustrated in Fig. 2. The vehicle shown is the moving object; if the window moves a matter of a few degrees in any direction it may pass out of the line of sight and obstruct the collimated beam of light. When a theodolite is located at a distance of 500 to 1000 feet away from the vehicle, the line of sight from the theodolite to the platform prism is easily vignetted.

• **Future developments** — Methods of azimuth alignment for deep space

probes in the future might employ a combination of gyro-compassing and star tracking. Gyro-compassing might be used as a coarse azimuth alignment previous to vehicle launch. The star tracker would then be used as a fine alignment sometime after launch. ⠿

Moon Launching

(Continued from page 35)

enough indicators on board to evaluate critical systems operation and enough reliability in the design, construction and initial checkout to preclude any other checks.

The decision as to what may be the possible malfunctions, what man would be able to repair in the allowed time, how much equipment could be carried to make these repairs must all be compromised with respect to risk, cost, time, space and booster capabilities. The result of this study will define additional items that may be classed as ground support equipment.

The capability to launch from the moon will first be a function of a successful landing within the design limits of the vehicle. The ability of on-board checkout equipment to satisfactorily give the status of the vehicle will be proved by the series of checks accomplished during the flight from the earth. The successful accomplishment of this portion of the flight will in itself imply reliability in all these systems with the exception of the lunar takeoff engine, and its succeeding satisfactory operation will give reason to expect high reliability in operation of the lunar takeoff engine.

The use of present inputs to the guidance system for lunar launch reduces the complications of the launching problem to the capabilities of the human crew.

The two highly contrasted operations in the earth-launching of lunar vehicles—with its expenditure of time, men, and machines in large quantities—and the unobserved, noiseless, uncomplicated launch of the lunar launch certainly appear realistic. However, the added complications of the earth launch are backed up by a great deal of ground support for everybody's safety. The simplicity of the lunar launch has its only safety in its built-in reliability resulting from a good design, good operating procedures—and a touch of luck. ⠿

Space GSE

(Continued from page 19)

volatile cryogenic fuels.

The blockhouse, although not located close to the launch pad, will have to be hardened to a degree unknown in present launch control complexes. There is no present facility that is capable of sustaining a direct hit by a malfunctioning missile. However, with a booster the size of *Nova*, it may be necessary to provide such a capability by constructing part of the blockhouse underground and hardening that portion above ground.

The launch pad for a *Nova* vehicle —located some 30 to 50 feet off the ground—must not only sustain a blast eight times that of the present *Saturn* but also be capable of being completely reconditioned and ready to accept another missile a week after the initial launch.

In addition to the facilities directly associated with the vehicle launch and control, a complex of industrial and biomedical facilities will be required to support the *Apollo* mission. All of these buildings—as indicated in the accompanying map—will have to withstand noise levels approaching that producing structural damage.

This discussion has centered around the launch facilities required for a *Saturn C-3* or *Nova* vehicle. Since some of the decisions relative to the launch vehicle have yet to be made, the basic parameters outlined may change. But whether the basic vehicle is solid or liquid or whether the lunar flight is direct or employs orbital rendezvous techniques, one basic truth will not change: the facilities required to put a man on the moon will far exceed both in size and complexity any that have yet been devised. ⠿

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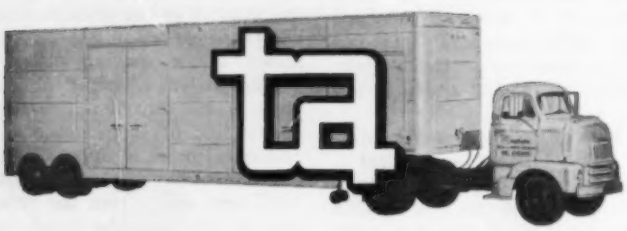

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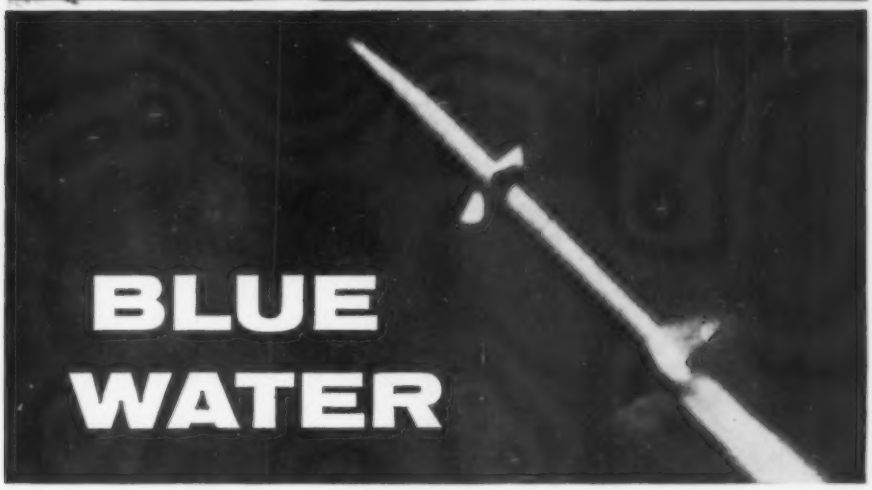

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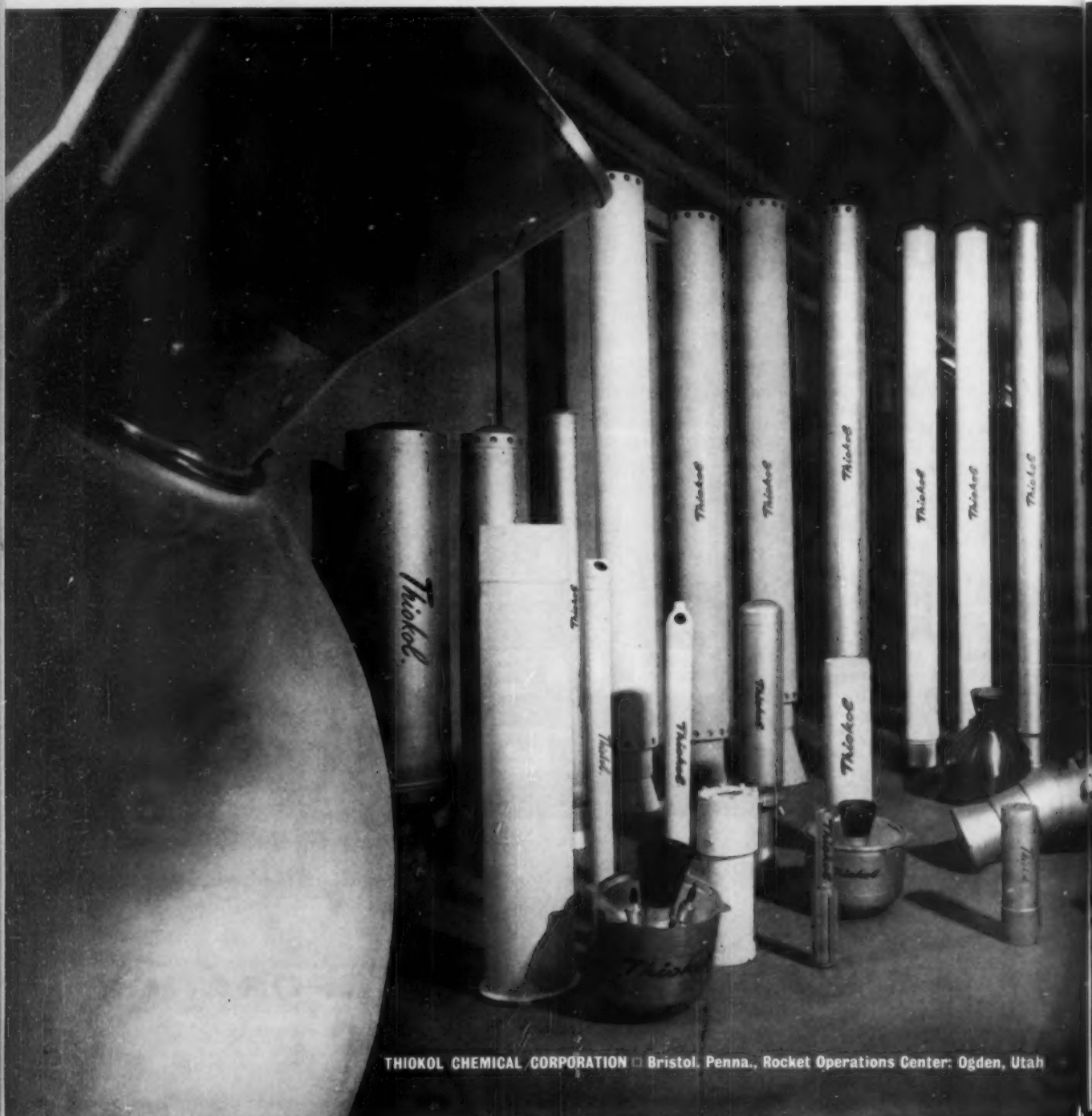

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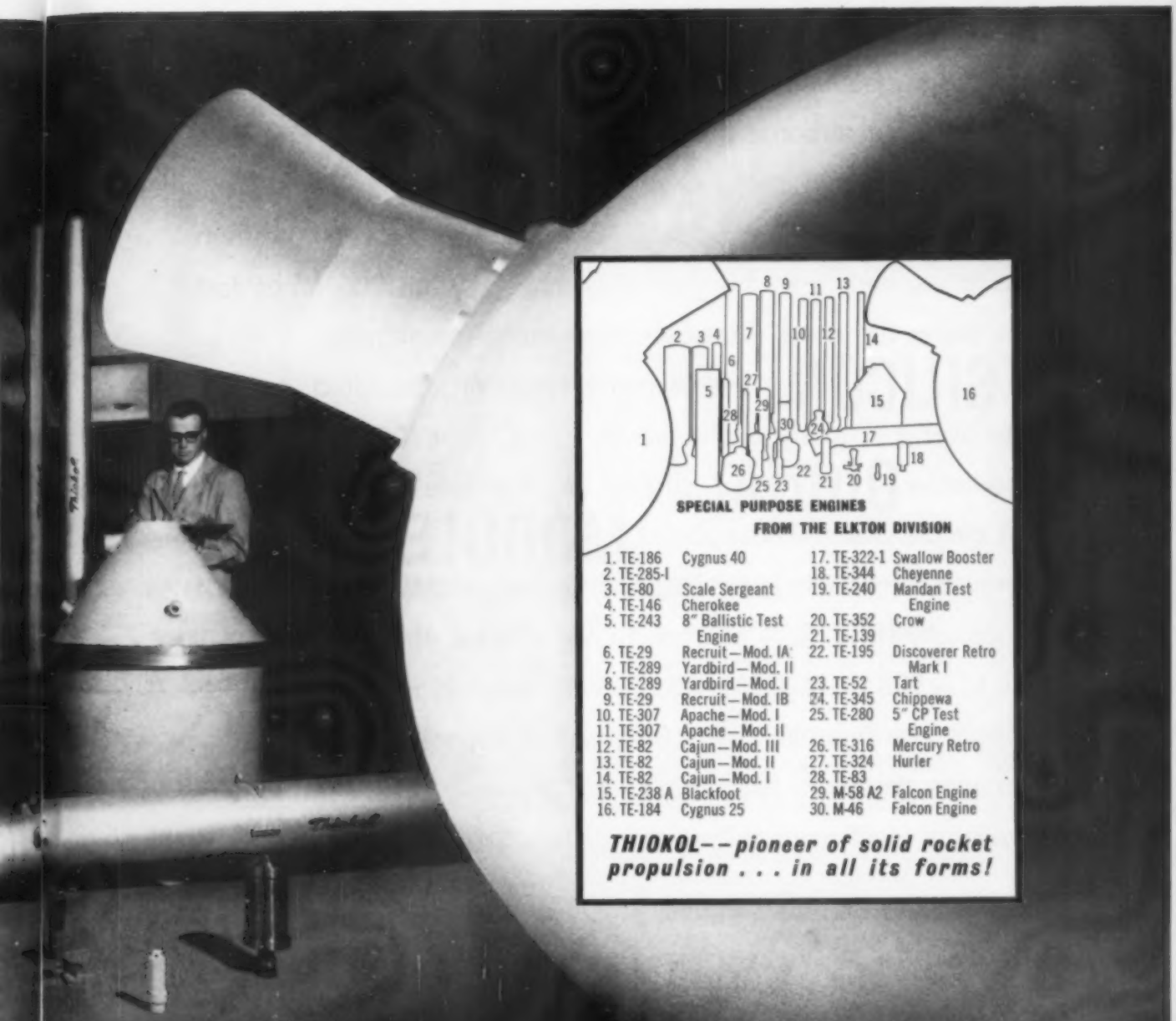

SPECIAL PURPOSE ENGINES
FROM THE ELKTON DIVISION

1. TE-186	Cygnus 40	17. TE-322-1	Swallow Booster
2. TE-285-I		18. TE-344	Cheyenne
3. TE-80	Scale Sergeant	19. TE-240	Mandan Test Engine
4. TE-146	Cherokee	20. TE-352	Crow
5. TE-243	8" Ballistic Test Engine	21. TE-139	
6. TE-29	Recruit—Mod. IA	22. TE-195	Discoverer Retro Mark I
7. TE-289	Yardbird—Mod. II	23. TE-52	Tart
8. TE-289	Yardbird—Mod. I	24. TE-345	Chippewa
9. TE-29	Recruit—Mod. IB	25. TE-280	5" CP Test Engine
10. TE-307	Apache—Mod. I	26. TE-316	Mercury Retro
11. TE-307	Apache—Mod. II	27. TE-324	Hurler
12. TE-82	Cajun—Mod. III	28. TE-83	
13. TE-82	Cajun—Mod. II	29. M-58 A2	Falcon Engine
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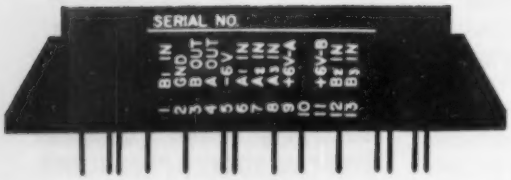

In less time than it takes light to cross this room, a new product, **DELCO'S NEW** high speed **10 MC** silicon modules, could: (1) correct the course of a missile in flight; (2) make it possible for sonar pickups to track and compute the position of targets with microsecond accuracy; and (3) handle any number of other airborne guidance and control functions that previous modules—due to low speed or environmental or performance limitations—could not handle. Delco Radio's 10mc modules, with a maximum gate-switch speed of 40 nanoseconds, convert data 100 times faster—even under the most extreme environmental conditions.

These **SILICON** modules come epoxy encapsulated, and operate over a temperature range of −55°C to +100°C. And these same reliable **DIGITAL** circuits are available packaged on plug-in circuit cards. These Delco **MODULES** are environmentally proved to: **SHOCK**, 1,000G's in all planes. **VIBRATION**, 15G's at 10 to 2,000 cps. **HUMIDITY**, 95% at max. temp. **STORAGE AND STERILIZATION TEMP.** −65°C to +125°C. **ACCELERATION**, 20G's. Designed for systems using from one module to 100,000, and the module's rated performance considers the problems of interconnection. Data sheets are available. Just write or call our Military Sales Department.

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SEPTEMBER 18

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Min-K, the unique insulating material developed and produced by Johns-Manville, now has an added quality . . . flexibility! Min-K is a new concept in missile insulation. The higher it flies, the better it insulates. Min-K's thermal conductivity drops as atmospheric pressure decreases. Its superior performance has been proved in hundreds of operational U. S. missiles.

New Flexible Min-K offers many special advantages. For example, it is the ideal way to lower prototype costs. You can test performance without the expense of special tooling. The flexible blankets lend themselves to bonding, lamination with reinforced plastics, service coatings and as a component of insulation systems. Further, Min-K can be tailor-made to wrap around a cylinder, cone or other geometric shape. And, it is also available in $1\frac{1}{2}$" and 2" tapes for spiral winding on a duct or pipe.

Because of the added quality of flexibility, Min-K's unique insulating characteristics now can be used in virtually unlimited new applications. For full details on Flexible Min-K, Min-K and other J-M aviation insulations, write Johns-Manville, Box 14, New York 16, New York. In Canada: Port Credit, Ontario. Cable address: Johnmanvil.

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Helium is one of the most valuable, most inert and most difficult gases to handle en masse in liquid state. One of Cryenco's special interests is designing and building custom helium equipment. Cryenco has designed refrigerators for the temperature range of 4°-20°K with small and large capacities. One of Cryenco's recovery-purifier plants produces Grade A helium at a rate of over 100 SCFM. Cryenco's efficient helium dewars and tanks range from 100 liters to 7000 gallons. Special 4° cryostats are also available. Let Cryenco handle your helium problems and free your physicists and engineers for fundamental work. Write for quotation on your specific requirement.

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Low temperature, high vacuum equipment and engineering, including Hydrogen liquifiers and accessory equipment.

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names in the news

Dr. William J. Perry and **Frank E. Butterfield:** Appointed director and chief engineer, respectively, Electronic Defense Laboratories, Sylvania Electric Products, Inc., a subsidiary of General Telephone & Electronics Corp. Other appointments are: **W. Herbert Lamb,** vice president of newly formed Microwave Device Div., Mountain View, Calif.; **Merle W. Kremer,** vice president, and **Daniel Echo,** product manager-display devices, Electronic Tube Div.; **Maxwell C. Scott,** manager-conversion and manufacturing for Mountain View Operations; **Larue D. Rexroat,** manager-government relations-Western Region, and **Jerome J. Weaver,** district marketing manager-Southeastern Region, Sylvania Electronic Systems; **John B. Donner,** manager-microwave and antenna laboratory, Waltham Laboratories; **Joseph E. Sheehan,** manager-market research and planning, and **Walter W. Smock,** product manager-militarized computers, Data Systems Operations.

George A. Banino: Elected vice president and general manager, Communications System Dept., ITT-Kellogg, a division of International Telephone and Telegraph Corp., Chicago.

Max J. Schuller: Promoted to manager, Semiconductor Device Development Section, CBS Laboratories, Stamford, Conn., a division of Columbia Broadcasting System, Inc.

Howard A. Zeimer: Joins Marks Polarized Corp., Whitestone, N.Y., as director of Military Liaison and Public Relations.

Ernest A. Reddle: Named manager of newly-formed Western Division, Navigation Computer Corp., Los Angeles. Before joining NAVCOR, Reddle was research engineer on the instrumentation of the *Ranger* lunar probe, Jet Propulsion Laboratory.

J. V. Naish: Former president of Convair and senior vice president of General Dynamics Corp., elected a director of McDonnell Aircraft, St. Louis.

Vernon H. Kiebler: Named electronic programs manager; **Stuart L. Dunkle,** Western marketing activities manager; and **Ray T. Prout,** Eastern marketing activities manager for Elgin National Watch Co.'s Industrial Group, as part of the company's expansion program into missile/space business. Prout will be in charge of the newly opened Washington, D.C., electronic and missiles office; Dunkle will supervise marketing activities at the Burbank and Chatsworth, Calif., facilities, and Keibler will have headquarters in Elgin, Ill.

Robert J. Segal: Appointed manager, Design Engineering, for high-speed message-switching centers being instrumented by the Radio Corporation of America in a nationwide U.S. Air Force communications system (ComLogNet).

ENGINEERS & SCIENTISTS
in the fields of space vehicle power and propulsion

The Propulsion and Power Systems Department of the Aerospace Vehicles Laboratory has several unusually interesting openings for engineers and scientists who are interested in the fields of space vehicle power and propulsion. The openings are at all levels of experience — from recent graduates to the senior staff level. Most of the positions will involve design and analysis of power and propulsion systems for satellite and space probe application. Specifically, some of the areas of specialization are:

1 SPACE POWER SYSTEMS
The positions will involve analysis and development of such energy sources as: photo voltaic, thermionic, thermoelectric, battery and advanced energy storage systems.

2 SPACE PROPULSION SYSTEMS
The positions will involve the preliminary and conceptual design and comparative analysis of all types of chemical and electric propulsion systems.

3 PROGRAM MANAGEMENT
The positions will be associated with the development of solid and liquid propellent rocket engines. Advanced degrees are preferred and considerable experience in the field will be required.

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Delmar M. Morris: Deputy director for administration at NASA's George C. Marshall Space Flight Center, died in Huntsville of a heart attack. Morris, who was 48, joined NASA in 1960. He had previously served with the Atomic Energy Commission.

Gordon R. Miller: Named manager, Avionics Section, U.S. Science Corp., Los Angeles. Prior to joining U.S. Science, Miller was manager of marketing programs and divisional chief engineer in charge of new product development for Whittaker Gyro Div., Telecomputing Corp.

James Hollis: President of Rixon Electronics, and **Gordon Frederick,** of Thompson Ramo Wooldridge, elected directors of White Electromagnetics, Inc. (formerly Don White Associates), Bethesda, Md.

Dr. Scott C. Daubin: Appointed head of marine sciences section, Sea Operations Dept., General Motors Defense Systems Div., Santa Barbara, Calif. Dr. Daubin recently resigned from the U.S. Navy, in which he held the rank of Commander.

F. M. Fulton: Named director of new Applied Science Division, Hycon Mfg. Co., Santa Paula, Calif. Fulton formerly was head of the Propulsion Development Dept. and assistant technical director for development of the Naval Ordnance Test Station, China Lake, Calif. He also was coordinator of astronautics for the station, and a member of the long-range Fleet Ballistic Missile Research Committee, Washington, D.C.

Robert F. Fallon: Appointed manager of Industrial Relations for Ford Motor Co.'s Aeronutronic Div., Newport Beach, Calif.

Louis B. Young: Named general manager of Bendix Corp.'s Systems Div., Detroit, succeeding **Roy J. Sandstrom,** recently promoted to the Mishawaka Div. in Indiana.

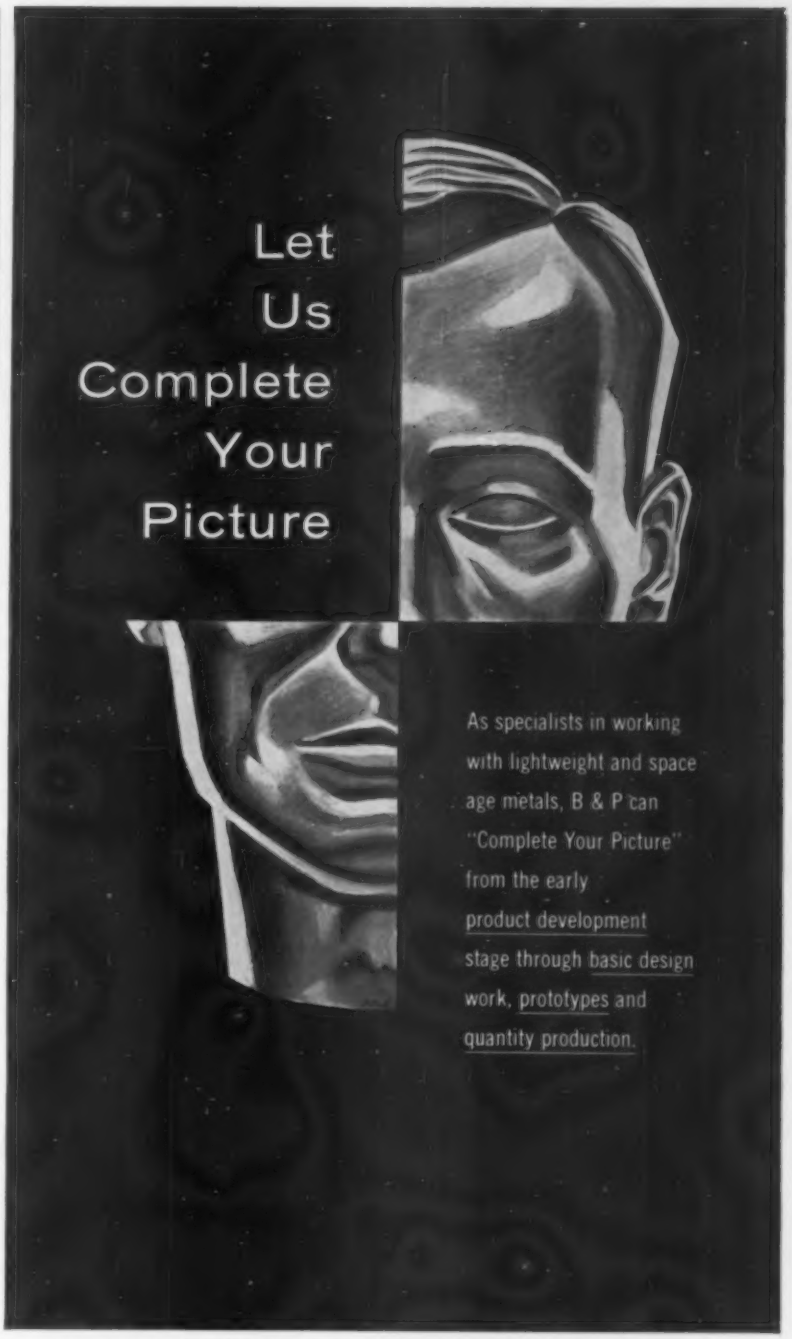
Will Mitchell, Jr.: With Allis-Chalmers Mfg. Co., Milwaukee, since 1947, appointed director, Research Division.

Harold Niles: Appointed government relations manager in charge of the Washington, D.C., office of Ford Instrument Co. Division of Sperry Rand Corp.

Dr. Chester H. McCall, Jr., and **D. Alan Kendall:** Promoted to research directors, Statistics, and Program Control, respectively, for Booz, Allen Applied Research, Inc., Bethesda, Md.

Charles W. Brunstetter: Promoted to general manager, Ipsen Industries, Inc. Brunstetter was responsible for the development of the Refractory Metals Division at Ipsen. He was formerly vice president of Astrometals Corp.

Jay M. Bedrick: Former chief engineer for Integron, Inc., named manager of electromechanical research and development dept. of Minneapolis-Honeywell's Boston Division.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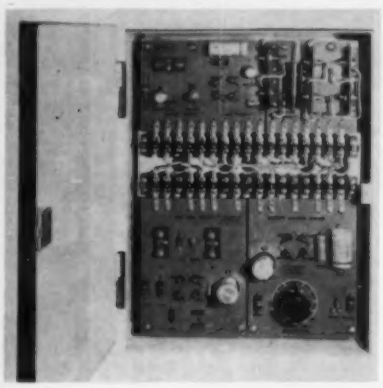


Variable Power System

Hevi-Duty Electric Co. is marketing a proportional power magnetic amplifier for precise electrical control application.

Coupled with a standard saturable core reactor, the amplifier is the electrical equivalent of an equal percentage change in process power. It takes signals from any control system with a 0-5 milliampere output, the process voltage and current, and combines these in a magnetic amplifier whose output is fed to the control winding of a standard saturable reactor.

This combination of signals and the high power gain of the D 77312 Magnetic Amplifier changes the typical characteristic curve of the saturable reactor to a proportional power relationship.

To simplify maintenance, the amplifier is constructed as five separately removable circuit panels installed in a heavy-gauge steel box with provisions for either flush or surface mounting. Any one of the sections can be removed independently of the others without changing or disconnecting any of the normal wiring to the device.

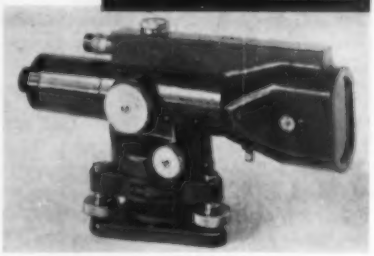
Circle No. 225 on Subscriber Service Card

Extension Swivel Fitting

Dumont Engineering Co. has developed a swivel fitting for fluid systems capable of accepting extension and contraction of its rotating end. This feature makes it possible for two sections of a fluid line system to be connected and then drawn together and sealed within an enclosure. The unit permits the fluid lines in each section of a missile to be connected by a rigid metal fitting. The connections are made when the fitting is fully extended. The unit is then con-

new generation

Autoset Optical Level



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The new Autoset Level is based on optical compensator, suspended free from all friction. It assures repetitive setting better than 1 second of arc. Autoset optical displacement micrometer reads height directly to .001" over a full ½" range.

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With this accessory the Autoset becomes an automatically horizontal collimator and auto-collimator.

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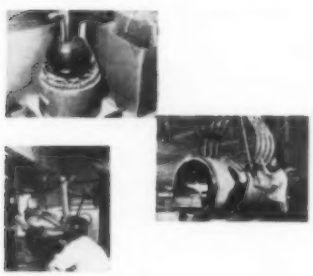

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tracted, permitting the two sections of the missile body to be brought together and sealed in the final assembly. The first units were made in the ¼-in. tube size. The entire assembly is only 10 in. long and ¾ in. in diameter. It achieves a full 6-in. extension without leakage, under high- or low-pressure service. The extension end of the fitting may also be rotated a full 360°.

Circle No. 226 on Subscriber Service Card

Miniature Tape Recorder

A multi-channel, miniature magnetic tape recorder, capable of operating through extreme environmental conditions—including up to 1000 g shock—is available from Borg-Warner Controls, a Division of Borg-Warner Corp. Designed for recording flight test information on advanced missiles and space

vehicles, the recorder, MR-21, is small and lightweight and can record up to 14 channels of data simultaneously on 1-in. magnetic tape. Total tape capacity is 69 ft. Among the important features of the MR-21 is a unique recording method which allows operation with either a-c or d-c input signals. Power requirements are extremely low, and wow and flutter are less than 1% under static conditions.

Circle No. 227 on Subscriber Service Card

Magnetic Multiplier

A miniature magnetic multiplier for converting the product of two electrical inputs into a single proportional a-c output is available from Transmagnetics, Inc. The device, designated Model 300AX, features a 1% full-scale multiplier accuracy. A d-c input current range of 0 to ±100 ua, plus an a-c input range of 0 to 2.3 volts, phase reversing, generates a phase sensitive a-c output from 0 to 1.2 volts—being directly proportional to the product of the inputs. Although these ratings are at

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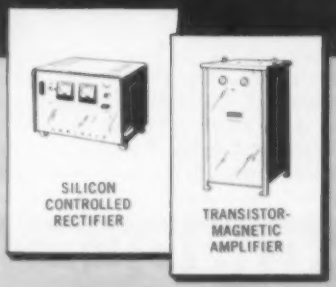

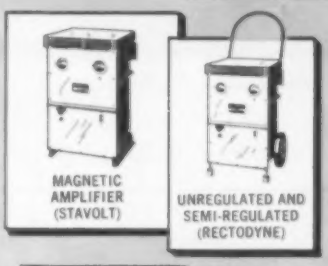

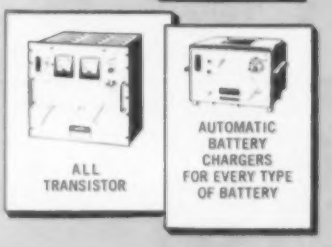

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400 cps, the Model 300AX is operable from 300 to 100 cps over a temperature range of −55° to 85°C. Two separate d-c inputs permit algebraic summation operations. All inputs and outputs are completely isolated.

Circle No. 228 on Subscriber Service Card

Miniature Floated Gyro

A miniature two-degree-of-freedom floated gyro of extreme inertial precision for long-duration space guidance systems is being produced by Arma Division, American Bosch Arma Corp. Designated the G8 gyro, it is only one-quarter the weight and one fifth the volume of the current Arma gyro in the *Atlas* inertial guidance system. The G8 contains an inner gimbal which is a sealed floated beryllium sphere containing the wheel assembly. Two degrees of freedom are provided by interposing a floated solid beryllium ring, having no moving parts, between the inner gimbal and the external housing of the gyro. Because of its ability to stabilize about two axes, only two G8 gyros are required for an inertial platform.

Circle No. 229 on Subscriber Service Card

Miniature D-C Amplifier

A highly stable solid-state, plug-in d-c amplifier has been developed by Quan-Tech Laboratories, Inc. The unit provides a gain of 10 and frequency response extends from d-c to 5% down at 100 kc. Stability of the amplifier approaches that of a chopper-stabilized unit, with typical drift being 3 mv up to 120°F, referred to the input. At constant ambient temperature, drift is no more than ± 250 uv.

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Time Delay Relay

Instantaneous recycling and multiple-contact time delay relays are available from Branson Corp. in a container that will directly replace older standard thermal delay relays. The MTRH4 time

delay relay, with an operating delay range of 1 to 90 seconds and an accuracy of ± 10%, 0.5-sec. minimum, features multiple output contacts. The MTRH8 is a voltage-compensated, instantly recycleable time delay relay with an operating range of 15 to 300 sec.

Circle No. 231 on Subscriber Service Card

Tiny Transistor Chopper

A miniature transistor chopper with its own self-contained drive transformer is available from Cambridge Division of Airpax Electronics, Inc. The chopper, Type 6022-3, is designed for use in printed circuit applications. The units

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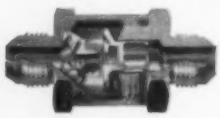

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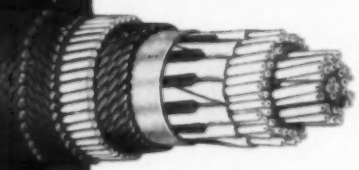

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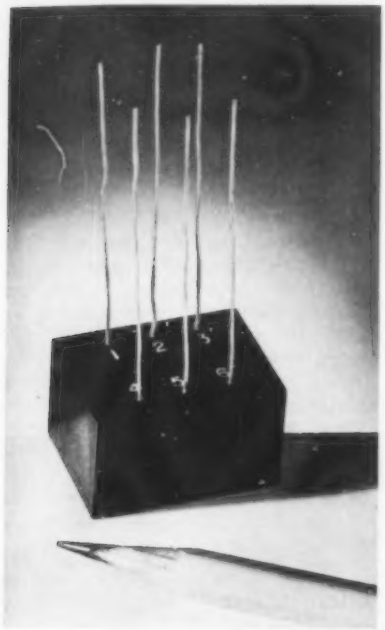


interrupt electrical current at very precise rates, and with minimum noise and offset. For example, weak d-c signals telemetered from great distances in space can be converted to pulses, and then amplified for accurate information "read-out." Used as a series shunt modulator, a typical printed circuit application, the Airpax 6022-3 maintains the noise level at 1 millivolt or less.

Card No. 232 on Subscriber Service Card

Non-Linear Pot Tester

A non-linear potentiometer conformity tester with tape-programed function control plus display and chart readout is available from Jonathan Electronics Corp. Operating on principles similar to those employed by programed automatic missile checkout equipment, the system electronically compares actual potentiometer voltage output with theoretical values at various incremental shaft positions. The automatic test system consists of four functional elements: an agular index head, an eight-channel punched tape reader, a control console and a dual-channel oscillograph.

Circle No. 233 on Subscriber Service Card

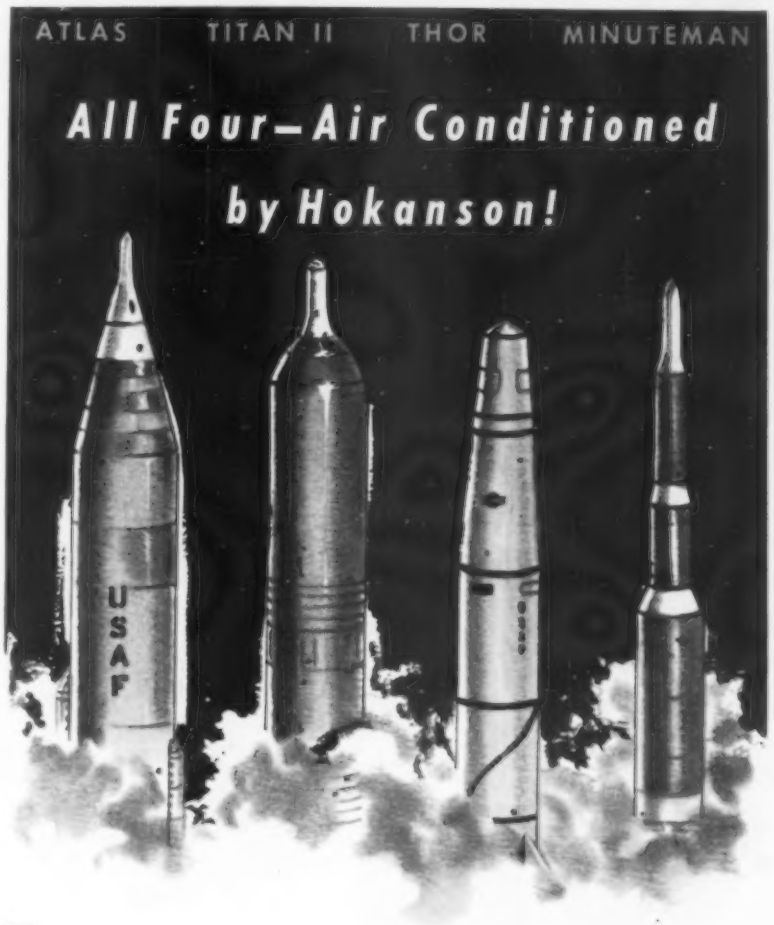
Moving Temperature Control

Continuous temperature measurement and temperature control of inaccessible, fragile or rapidly moving objects, at temperatures as low as 300°F, is now possible with the Pyrotel Model PY45, manufactured by Mason Instrument Co. The incorporation of a synchronous chopper assures stability, sensitivity and rapid response times of 20 milliseconds, thus enabling accurate, repeatable temperature readings on targets such as wire travelling at 5000 ft. per minute. The precision-built detector head permits temperature reading of targets as small as 0.0003 wire or as large as "the side of a barn."

Circle No. 234 on Subscriber Service Card

Ceramic Base Material

A ceramic material, developed especially for use as a base for carbon-deposited and metal-film resistors, is



The "Big Four" land-based strategic surface-to-surface U.S. missiles—Douglas Thor, Convair Atlas, Martin Titan II, and Boeing Minuteman—are backed by multiple production ground support air conditioning units engineered and manufactured by the C. G. Hokanson Company, Inc. This "grand slam" award of all four competitive *production* contracts is the best evidence that the name Hokanson is a guarantee of design excellence, performance, and reliability in ground support air conditioning.

C. G. HOKANSON COMPANY, INC.
2140 Pontius Avenue • Los Angeles 25, California

Hokanson

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available from Centralab, The Electronics Div. of Globe-Union Inc. Designated as Centralab Body 702, this material can be supplied in a wide range of diameters and lengths.

Circle No. 235 on Subscriber Service Card

Vacuum Thermocouples

A complete range of miniature vacuum thermocouples (Vacuo Junctions), including an entirely new design, are available from Barker Sales Co. Manufactured by Best Electrics Co., the regular range of the couples includes "Standard" types for low and audio frequencies—with heater ratings from 1.25 milliamps and up—and ultra-high-frequency types for r-f applications from 5-milliamp heater ratings. The UHF types have straight-through heaters and low intercapacity. Unmounted, open-wire thermocouples are also available for meter manufacturers.

Circle No. 236 on Subscriber Service Card

Personal Radiation Monitor

Nuclear Materials and Equipment Corp. (NUMEC) is marketing a miniature persoanl radiation monitor. The NUMEC PRM weighs only 3.5 oz. About the size of a fountain pen, the PRM's components are contained in an easily decontaminated stainless steel casing. Worn in the breast pocket of the user, it provides simultaneous chirping sounds and light flashes at frequency intervals in proportion to the amount of gamma radiation present in an area. The distinctive chirping sound is near the point of maximum sensitivity on the hearing curve, 2800 cycles per second.

Circle No. 237 on Subscriber Service Card

Micro-Micro Ammeter

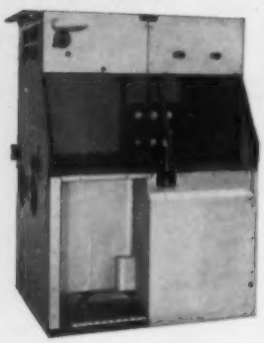
Radiation Technology, Inc. has announced a low-drift micro-micro ammeter designated the Model R660. A highly stable, temperature-compensated, transistorized amplifier with an electrometer tube input is arranged so as to produce almost 100% feedback. This results in a low input impedance and reduces drift due to changing electrometer tube characteristics. The instrument has twenty ranges from 3×10^{-3} to 1×10^{-12} amperes full scale. Drift is less than $\pm 2\%$ of full scale per week after an initial warm-up of less than 10 min.

Circle No. 238 on Subscriber Service Card

Digital Transmission

A digital data transmission system, CTDS 2400, has been developed by Hallicrafters to allow data acquisition and processing systems to communicate over low-cost, universally available, commercial-quality voice communication channels. High-speed transmission of digital data, with maximum reliability, can be accomplished without em-

Radar Console



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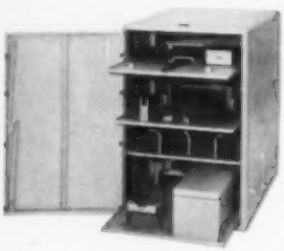
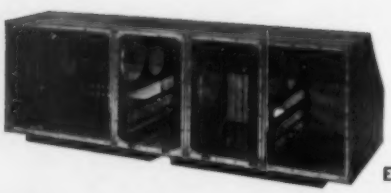
Radar Reflector

Electronic Frame

Storage Cabinet





Electronic Rack

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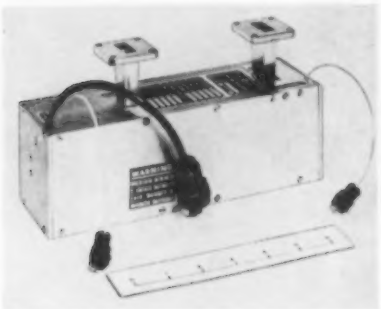
Circle No. 41 on Subscriber Service Card

ploying many costly equalization networks. The Hallicrafters CTDS 2400 system—consisting basically of a transmitter and a receiver—converts binary pulses to an audio frequency signal which can be transmitted and demodulated in the receiver to yield the original signal with a maximum error possibility of only one bit in a hundred thousand. The system transmits at the preferred military field data rate of 2400 bits per second.

Circle No. 239 on Subscriber Service Card

Traveling—Wave Amplifier

A low-noise, metal-ceramic traveling-wave tube amplifier for use in the 7500-8500 megacycle frequency range is available from the Power Tube Dept. of the General Electric Co. The tube, designated Z-3093, has a maximum noise figure of less than 7.5 db and a



saturated power output of five milliwatts across the entire band. Gain is at least 25 db. The Z-3093 is supplied as a complete package, including the permanent magnet focusing assembly and waveguide input and output r-f connectors.

Circle No. 240 on Subscriber Service Card

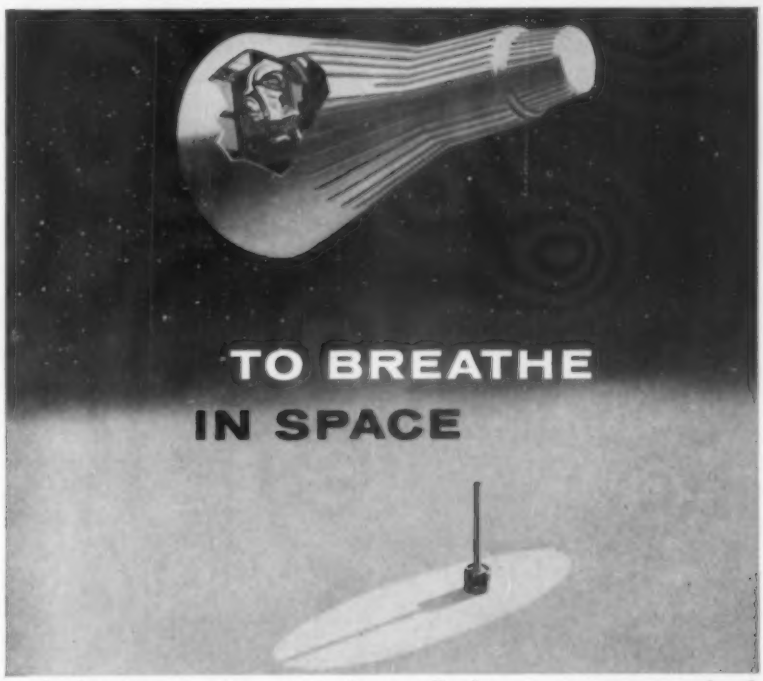
Component Container

FleXi-pak, a storage container offering a new approach to the packaging problem, is being marketed by Royal Jet, a division of Royal Industries, Inc. Fabricated from aluminum, the lightweight product couples variety and simplicity of design by using basic engineering components for a number of package specifications. This feature, called modular construction, permits great flexibility in meeting demands for package size, while the repeated use of basic design components reduces engineering and tooling costs. The container is designed to absorb a significant amount of shock. FleXi-pak's added protection permits a less complex shock-mount support system for the packaged unit, and formed-skin protrusions on the shell provide bumpers which protect accessories and instruments mounted or housed on the outer shell. Providing the advantage of controlled atmosphere storage, the flexible container is equipped with free-breathing valves, an indicator for internal humidity and sealing nested between specially designed aluminum extrusions.

Circle No. 241 on Subscriber Service Card

Three-Port Circulator

A high-power broadband three-port circulator is being marketed by Kearfott Microwave Division, General Precision, Inc. The circulator may be converted into a microwave switch by replacing the permanent magnet with an electromagnet. Models with power-handling capabilities of 50 kw or more are avail-



The first American Astronaut in Space will rely on a continuous supply of oxygen metered through intricate valving which has been designed by Garrett Corporation, AiResearch Manufacturing Division, engineers with the technical assistance of Stillman Rubber Company experts.

To produce a reliable poppet in sub-miniature size which would meet micro-precision requirements, Stillman Laboratories developed a special compound designed especially for NASA's Project Mercury. This compound, TH-1080, was bonded under critical conditions to the stainless steel body and shaft, and the poppet then ground to precision tolerances.

By close coordination with Garrett engineers, Stillman technicians were able to produce this precision part in only four days from the design release date. Stillman's reputation for quality and reliability in the aircraft and missile industry, together with years of technical experience and know-how, enabled them to produce and deliver the all-new, sub-miniature poppet in record time. These same qualities of experience and technical abilities are available to any industry or manufacturer who specifies the very finest of static and dynamic sealing.

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For further information, write on company letterhead to Preliminary Design Engineering Dept., FMC Ordnance Division, P.O. Box 367, San Jose, California. Phone: CYpress 4-8124.

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PUTTING IDEAS TO WORK FOR NATIONAL DEFENSE

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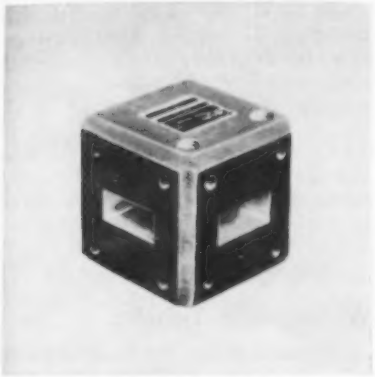

able on request. Outstanding features of the new three-port circulator are: frequency range; 8.0-10.5 kmc; isolation: 20 db min.; insertion loss: 0.4 db max.; vswr: 1.20 max.; power: 25 kw peak, 25 w average; connectors: mate with ug/39/u.

Circle No. 242 on Subscriber Service Card

High-Temp Transducers

A series of ultradyne pressure transducers designed to provide accurate measurements with ambient temperatures as high as 1000°F and to have high resistance to nuclear radiation is being marketed by Consolidated Controls Corp. Available as gauge, absolute and differential pressure measuring devices, transducers of the 411 series provide nominal full-scale output of 200 millivolts with an accuracy of 2½% over the entire temperature range from −65 to 1,000°F. At room temperature, accuracy is 0.5%; over any 250° span, 0.1%. Units are available with full-scale measurements ranging from 0.6 to 5,000 psi.

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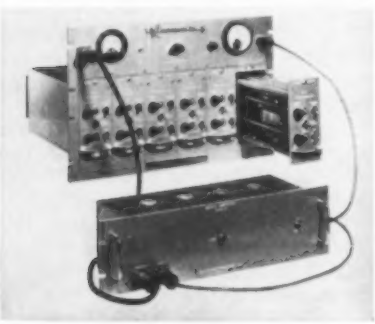
Strain Gage Conditioner

The B & F Instruments, Inc. Model 1-400 Servomatic Modular Strain Gage and Transducer Input Conditioner accommodates any type of resistance strain gage or transducer. Each module contains its own individual floating



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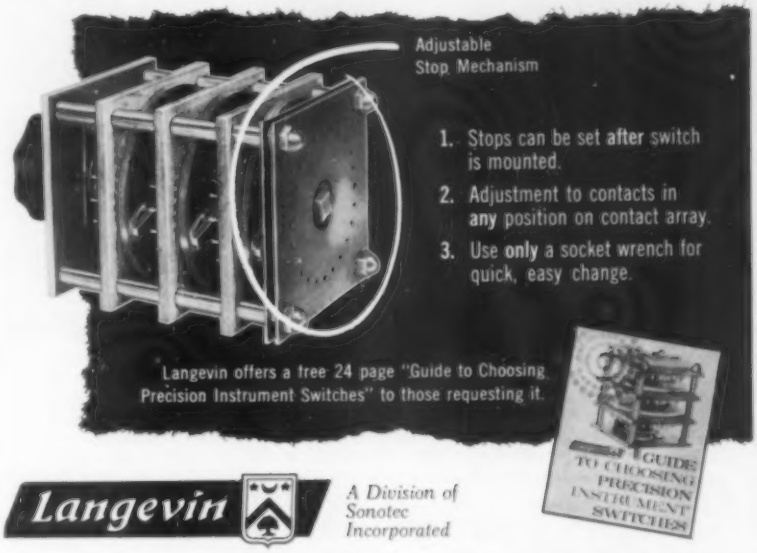
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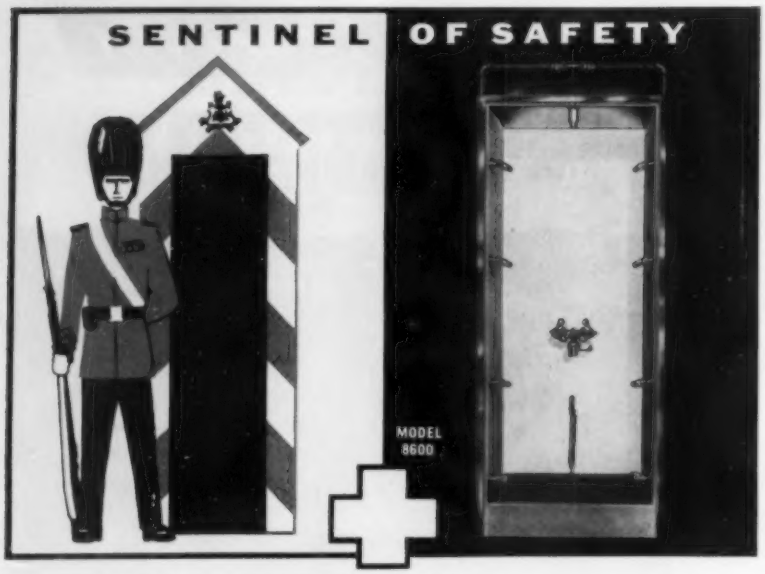

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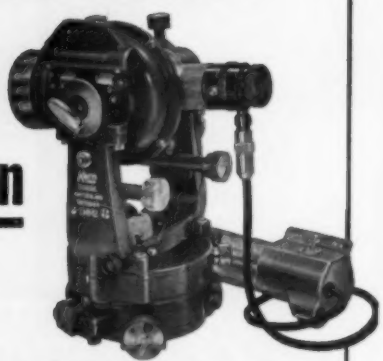

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power supply. The necessary sophistication has been added so that the depression of one pushbutton will cause automatic servo balancing and automatic setting of the sensitivity control.

The servomatic system will null to ± 10 microvolts. A unique manual override is provided for normal manual balancing and voltage selection. The automatic calibration feature is also part of this new conditioner.

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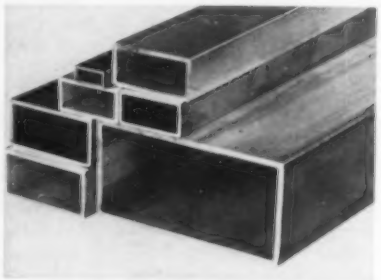
Waveguide Tubing

Precision grades of coin silver waveguide, in frequencies from 18 kmc to 325 kmc, are in regular production and available from Horton-Angell Co. Special sections, C-band and smaller, to



any dimension and tolerance, can be rapidly produced in a variety of materials including steel, aluminum, brass, copper, invar, and laminated metals of

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Double Triode

A medium-mu VHF double triode has been added to the strap-frame subminiature electron-tube line of Sylvania Electric Products Inc. The unit, Type 8103, is designed for use as a cathode-follower or RF amplifier-mixer in hybrid systems. Because it has 26.5-volt heater and plate operation, the tube requires no special plate or heater supply circuits. The double triode structure enables the tube to replace two or more vacuum or solid-state devices.

Circle No. 246 on Subscriber Service Card

Hi-Q Disc Feed-Thru

A disc feed-thru capacitor is available from the Hi-Q Division, Aerovox Corp. Designated type 1107, the completely encapsulated unit employs a ceramic disc as the dielectric. Resonant frequency is higher than 1000 mc. The discoidal construction provides efficient shielding of radiation in the frequencies of UHF and VHF TV bands. The capacitor is available in a capacity range from 5 to 1000 mmf with a 500 d-c working voltage.

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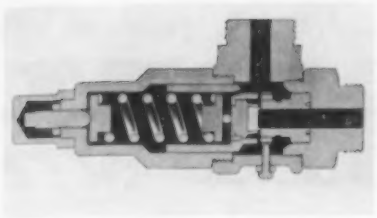

Positive-Seating Valves

An adjustable, positive-seating relief valve for liquid or gas service to 5000 psi is available from the Combination Pump Valve Co. Combining a resilient, flat-seated nylon disc with guided lift design, the valve maintains a tight, leak-proof seal until the present pressure is exceeded. Problems of leakage caused by spring deflection and galling in metal-to-metal seated valves are completely eliminated.

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new literature

STRAIN GAGE — "38-G Silicon Semiconductor Strain-Gage Pressure Transducer," a brochure describing the Fairchild solid-state pressure transducer line is available from Fairchild Controls Corp. The brochure contains design and performance data on both the airborne and ruggedized versions of the 3S-G.

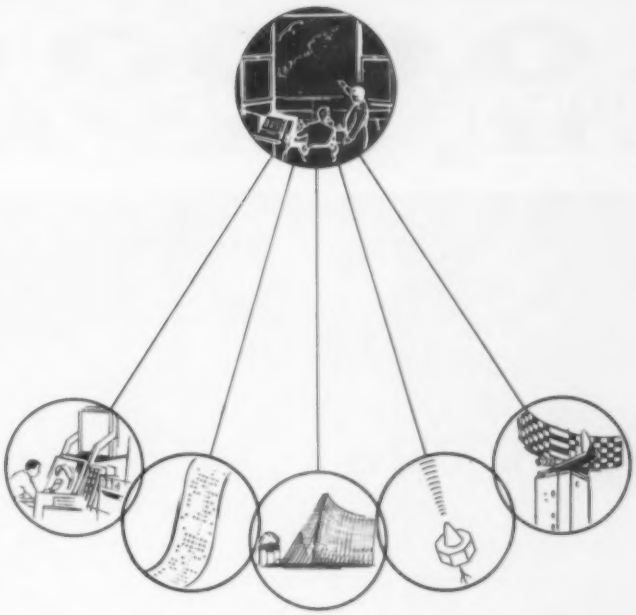
Circle No. 200 on Subscriber Service Card

ELECTRONIC TIMING SET — Four different applications using digital time signals to coordinate remote equipment in complex instrumentation and data-processing systems are described in a brochure available from Hallicrafters. Examples include: (1) airborne reconnaissance with automatic data logging, (2) ground timing system for test ranegs and missile sites, (3) data processing with time compression and expansion features, (4) ground support equipment for performance checkout.

Circle No. 201 on Subscriber Service Card

MISSILE ALLOYS—A booklet on high-temperature, high-strength alloys used in the aircraft, aircraft engine, gas turbine, missile and any other applications where corrosion resistance and high strength at elevated temperatures are needed, is available from Alleghany Ludlum Steel Corp. It features a series of steels and alloys, each with its own individual leaflet, together with a 28-page general booklet on high-temperature alloys. While all the materials are treated in the general booklet, each steel or alloy is treated in detail in the accompanying individual leaflet. Eleven alloys are treated individually.

Circle No. 202 on Subscriber Service Card



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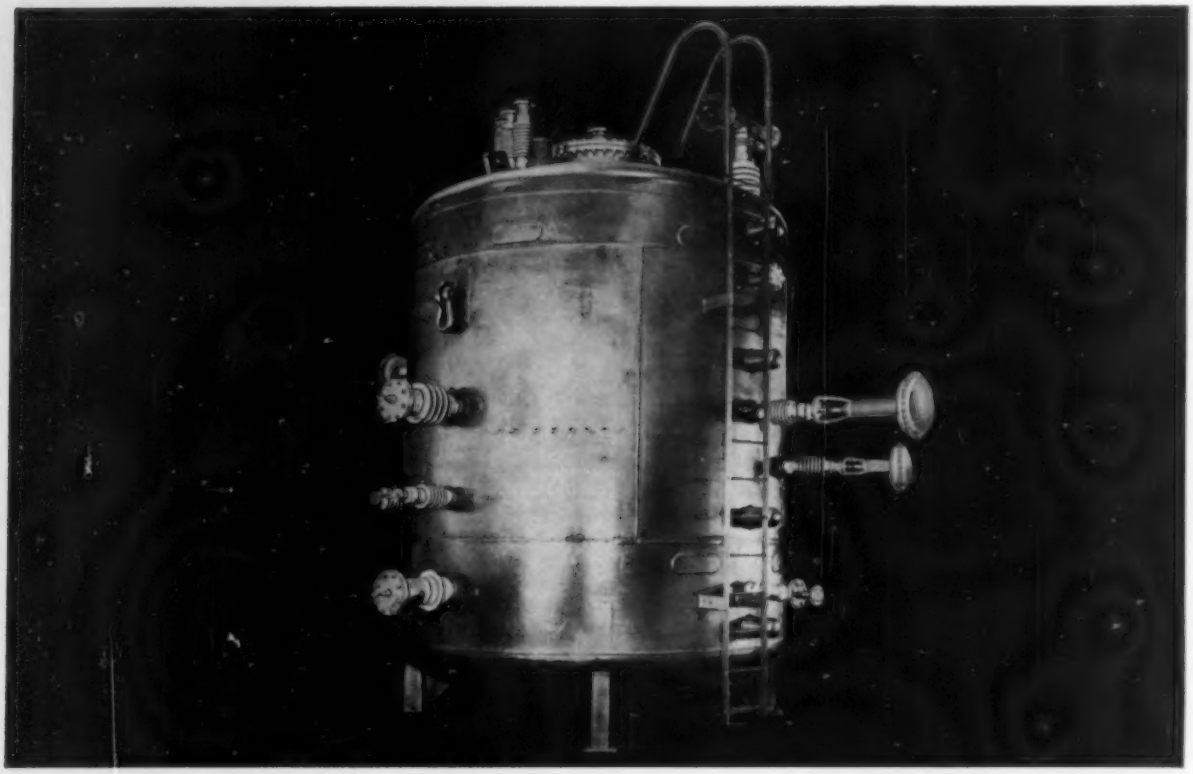

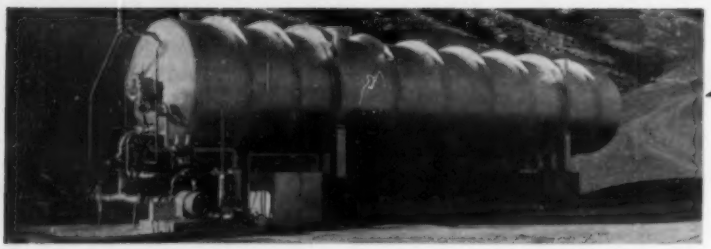

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Circle No. 19 on Subscriber Service Card

For Mercury Atlas . . .

Another Unmanned Shot Planned

NASA says three-orbit flight is needed to test out capsule before putting man in it; astronaut trip unlikely this year

by Hal Taylor

ANOTHER TRIAL run will be conducted with *Mercury Atlas* before the United States risks putting a man into orbit.

The decision for the second shot—hot on the heels of last week's successful one-orbit first flight of a *Mercury Atlas* carrying a "robot" crewman—means there is only an outside chance of a U.S. manned orbital flight taking place this year.

Dr. Robert C. Gilruth, Project *Mercury* head, and NASA Administrator James E. Webb both declared that one more shot is needed before a manned flight attempt. It has not been decided whether the capsule will contain another robot or have a monkey aboard.

With six to eight weeks required between *Mercury* shots, the space agency will be hard-pressed to achieve its goal this year.

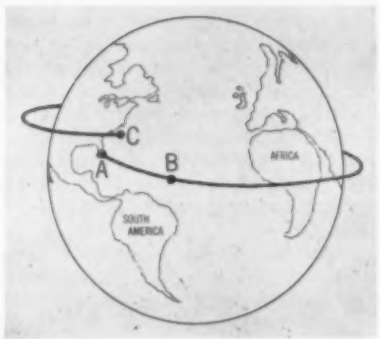
Any long delays because of weather or technical difficulties experienced during earlier *Mercury Redstone* and *Mercury Atlas* shots would push the timetable for manned flight into 1962.

NASA officials hailed the success of the *MA-4* shot and the successful recovery of the capsule by a Navy destroyer. Preliminary information indicated that all systems worked well. The capsule was injected into orbit at an altitude of 100 miles and reached a perigee of 158.6 miles. Top velocity reached during the one-hour-and-49-minute flight was 17,519 miles per hour.

While officials claimed the shot proved that manned flight was possible, they said another unmanned flight was necessary to further test the *Mercury* spacecraft and attempt a three-orbit flight like that planned for the first manned shot.

• **Hatch test vital**—Principal reason for another flight is to test the explosive hatch mechanism which malfunctioned during the suborbital flight of Astronaut Virgil Grissom in *MR-4* July 22.

The capsule used in the *MA-4* flight was not equipped with the explosive hatch. The *MA-4* capsule is an early model. Only *Mercury* spacecrafts from Number 7 onward are equipped with the new hatch.



MA-4 took off from Cape (A), orbited at (B). Capsule was picked up at (C).

Officials said the more modern hatch was not used on the *MA-4* flight because "they are not available in large numbers."

The *MA-4* capsule did not have a landing bag to cushion the shock of impact. As a result, the capsule impact was harder than it would be for a manned flight.

Final reason cited by officials is the need to fly an unmanned three-orbit mission so that the capsule, retrorockets, and recovery forces can be checked over the same period that the first American orbiting astronaut will be subjected to space flight.

• **Smooth success**—NASA officials were especially pleased with the performance of the *Atlas* booster and the *Mercury* tracking network. Technical difficulties which plagued earlier *Mercury Atlas* shots were absent in *MA-4* as the big booster lifted cleanly from its pad, developed the desired thrust and injected the *Mercury* capsule into orbit at the planned altitude.

Each station on the Mercury Tracking Network picked up the capsule on schedule and was read "loud and clear" by control centers at Cape Canaveral and Goddard Space Flight Center.

Officials were gratified by the accuracy of the flight. Chutes designed to slow down the capsule after re-entry into the atmosphere opened only 21 sec. after the planned time, and the impact area south of Bermuda was only 39 miles from the "nominal" landing area.

There was one malfunction which NASA officials said would require further study. The mechanical man simulator in the spacecraft used up an unusual amount of oxygen. It was possible there may have been a leak in the system. Oxygen use of the same volume during a manned flight would force the astronaut to abort after one orbit.

Pressure in the spacecraft during the flight registered a high of only 7½ g, less than has been recorded during the suborbital flights. Other figures released included: weight of spacecraft at launch, 3900 lbs., weight in orbit, 2700 lbs. and weight at impact, 2200 lbs.

• **A minor problem**—One other difficulty cropped up when communications between the capsule and ground stations was lost for a time over the Pacific. This was blamed on the tape recorders in the capsule. It was classed as a minor problem because the astronaut will communicate directly with the ground stations.

There was no visual contact with the capsule as it re-entered the atmosphere and impacted in the Atlantic. It was tracked by radar on the recovery ships, however and a Marine helicopter hovered over it shortly after impact. The capsule remained in the water well over one hour while the recovery ships raced toward it.

NASA said the successful *MA-4* flight proved that:

—The spacecraft can withstand the 2000°F heat of re-entry.

—The modified *Atlas* launch vehicle can release the spacecraft at the precise speed, altitude, and flight-path angle for orbital flight.

—The spacecraft systems can operate on a fully automatic basis for nearly two hours.

—The braking rocket system can bring the craft safely down from orbit. ¤

Spring launch date . . .

First Details of Ranger III's Lunar

Surviving capsule to use retrorocket to slow speed for hard landing; impact velocity of 108 ft./sec.

THE BALSA-CUSHIONED *Ranger III* instrument capsule will use its own retrorocket to slow its speed to under 150 miles an hour when it impacts the moon.

NASA has released first details of the spherical capsule, scheduled to be launched early next spring as the first U.S. effort to hard-land instrumentation on the moon.

The 56.3-lb. globe is the only part of the *Ranger III* vehicle which is intended to impact safely. About 20 to 25 miles above the lunar surface, the instrument capsule will be separated from the main craft. Its retrorocket will slow its final closure rate to under 150 miles/hour, and, it is hoped, land its vital physical measurement devices intact.

The rest of the vehicle will continue at roughly 5000 miles an hour and be destroyed when it hits the moon's surface. Among its several experiments, the main craft will employ a low-resolution TV camera to transmit pictures of the lunar surface back to earth as it descends.

The *Ranger* spacecraft is now under development at the Jet Propulsion Laboratory in Pasadena, Calif. The capsule itself is being developed for JPL by Aeronautic Division of the Ford Motor Company in Newport Beach, Calif.

• **Eight to go**—The National Aeronautics and Space Administration says present plans call for launching a total of nine *Ranger* vehicles. The program is a prelude to a manned lunar landing by 1970.

Ranger I, launched on Aug. 23, was designed to test hardware and technology in a highly eccentric earth orbit. Its orbit was too low, but its instruments worked satisfactorily.

Ranger II will be launched in October on a similar mission to complete Phase 1 of the program. *Ranger III* will be the beginning of Phase 2, and will be followed by two similar attempts.

• **First capsule details**—The survival sphere now being built by Aeronutronic is a 12-in.-diameter shell containing a seismometer, temperature recorders, supporting electronics, and power supply. The instrument shell is nested within an approximately 6-in.-thick outer shell of balsa wood. Nearly 8 lbs. of flotation liquid separates the inner package from the wood, helping to distribute the structural loads on final impact. Overall package size is 25 inches in diameter.

The liquid also permits the inner sphere to return to a vertical position (by lunar gravity) after landing. The sensitive seismometer will then be in the correct attitude to transmit its data to earth.

As soon as the package comes to rest it will begin its data collection. Battery-powered, it is expected to continue transmissions for up to several months.

It is essential, said Aeronutronic engineers, that the capsule be capable of continuous operation in the rugged lunar environment. The temperature range is from −250°F at night to as high as 220°F during the day.

To maintain a near-constant temperature within the instrument package, vacuum insulation is used. In addition, 3.6 lbs. of water ballast is included to aid in controlling temperature variations.

To avoid contaminating the moon, the entire *Ranger* spacecraft will be biologically sterile (M/R, March 20, p. 27). All internal instruments will be biologically sealed to insure against reintroducing contaminants.

• **Retro and spin system**—After release from the *Ranger* craft, the capsule package will include a retrorocket motor and igniter system; spin motor and igniter system; altimeter and antenna, plus all necessary support structures. Total weight of this assembly is 325 lbs.

Hercules Powder Co. is developing the small solid-propellant retrorocket. The almost 200-lb. motor is dynamically balanced to minimize alignment errors when the capsule is spin-stabilized.

The three-jet spin rocket system for stabilization is being built by Aeronutronic. It will be located within the cone of the rocket nozzle.

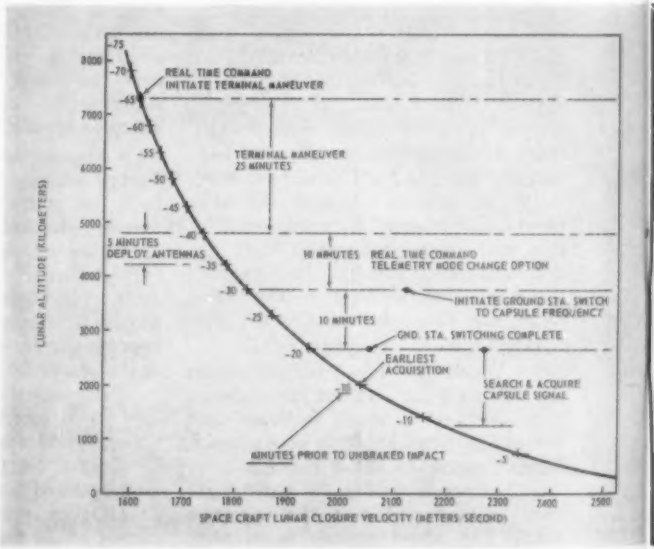
When the retrorocket is ignited, the entire spin unit is jettisoned.

A 5-lb. altimeter built by Wiley Electronics Co. will initiate the terminal phase of the *Ranger III* journey.

Since an accurate figure is not known for the distance between the earth and moon, separation of the survival capsule cannot be programed. A radio signal from earth will activate the

Terminal Trajectory

Three curves trace final 75 minutes of Ranger III flight to hard impact of survival capsule on lunar surface.


REAL TIME COMMAND INITIATE TERMINAL MANEUVER
TERMINAL MANEUVER 25 MINUTES
5 MINUTES DEPLOY ANTENNAS
10 MINUTES
REAL TIME COMMAND TELEMETRY MODE CHANGE OPTION
INITIATE GROUND STA. SWITCH TO CAPSULE FREQUENCY
10 MINUTES
GND. STA. SWITCHING COMPLETE
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SEARCH & ACQUIRE CAPSULE SIGNAL
MINUTES PRIOR TO UNBRAKED IMPACT
LUNAR ALTITUDE (KILOMETERS)
SPACE CRAFT LUNAR CLOSURE VELOCITY (METERS/SECOND)

Instruments

altimeter as *Ranger* nears the moon.

The radar-pulse-type altimeter, using reflections from the lunar surface, will determine range accurately. At the correct distance, it will generate the separation signal.

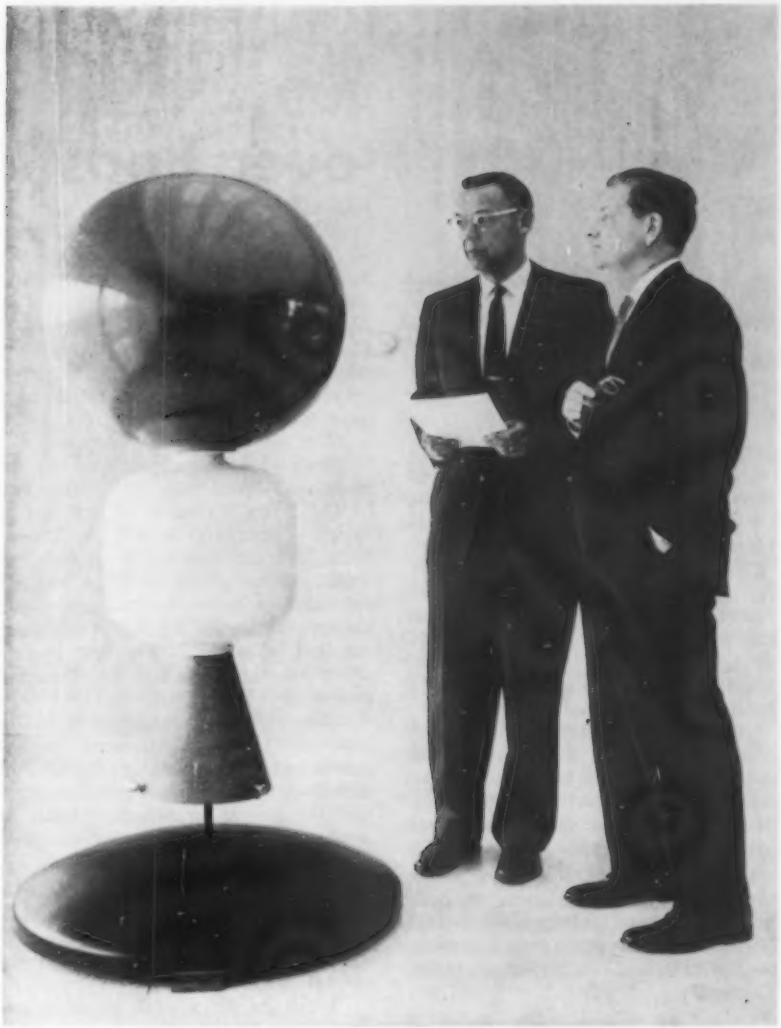
• **New rocket design**—The capsule rocket assembly employs the latest in rocket design principles, according to Hercules.

The motor uses a sliverless, very-high-impulse, composite-modified, double-base propellant charge. The fuel is cast within and is bonded directly to a Spiralloy rocket case.

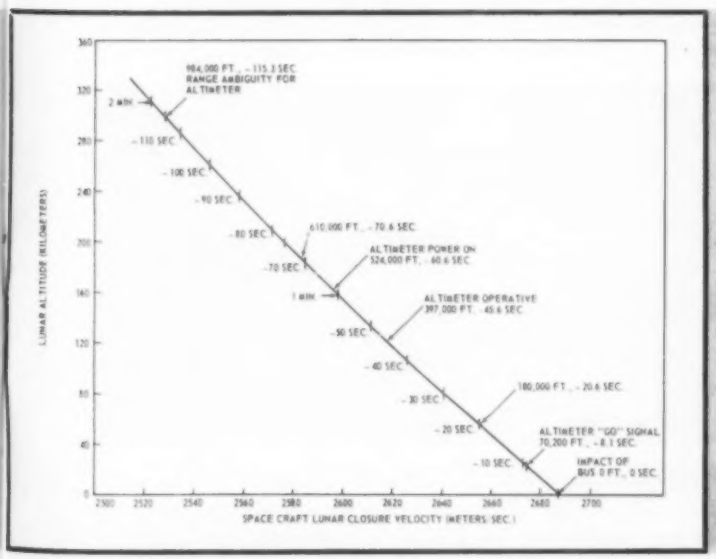
Composite-structure chamber consists of a forward plastic closure, aft aluminum adapter, insulator, Spiralloy vessel, and fore and aft attachment fittings. The chamber, insulator and aft skirt are all wound on a mandrel; the insulator of nylon-phenolic and the chamber and skirt of Spiralloy. The insulator is required to protect the Spiralloy chamber in the areas where the slots in the propellant charge expose the chamber to hot combustion gases during burning.

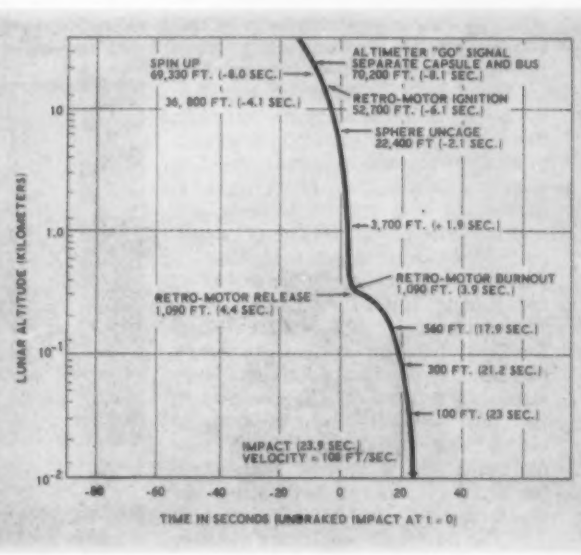
The loaded and assembled motor weighs 195.8 lbs. and measures 31 in. long and 18 in. in diameter.

Developers say a velocity increment of 9180 ft./sec. is produced by the retrorocket for a 91.6-lb. load. ❖



SURVIVAL CAPSULE built by Aeronutronic for JPL's Ranger III is shown in full scale. Top section is instrument capsule; lower section is retrorocket motor assembly. Two of three spin stabilization jets can be seen at bottom.

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36, 800 FT. (-4.1 SEC.)
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On the lunar front . . .

Policy Split over Boosters Reported

Golivan Committee is also said to be arguing about 'wasted' time; NAA wins $140-million S-II award

BITTER CONTROVERSY is understood to be raking the top policy group charged with working out a national space vehicle program.

The main sore points are said to be: A running argument over the relative merits of solid versus liquid big boosters; crossfire between NASA and DOD members of the group about the time being "wasted" in getting the lunar space vehicle program moving.

Lack of agreement on major issues among members of the Golivan Committee, which is to make a summary report to the White House by the end of October, became known amid these other developments:

—NASA awarded a $140-million contract to North American Aviation Inc.'s Space and Information Systems Division for developing and building ten 800,000-lb.-thrust *S-II* stages for the *Saturn C-3*.

—NASA Administrator James E. Webb reported that an *Apollo* spacecraft contract may now be awarded before the end of the year.

—The space agency prepared to announce a bidders' conference, to be held late this month, on contracts to build first stages of the *Saturn C-1* and *C-3*.

Significantly, NASA announced in the *S-II* stage award to North American that it plans to use two *F-1* (1.5-million-lb.-thrust) engines to power the first stage of *Saturn C-3*. However, it is understood that this decision is still under review by the Golivan Committee, which also has yet to finally approve the scrapping of *Saturn C-2*. (M/R, Aug. 7, p. 13).

Informants told MISSILES AND ROCKETS that Aerospace Corp. members of the Golivan Committee were vigorously supporting solid lower stages for big boosters in opposition to NASA's Marshall Space Flight Center representatives, who were holding out for liquid. Said one expert close to the situation:

"The Marshall people are refusing to admit that solid may be quicker and cheaper than liquids."

DOD members were complaining that the continuing deliberations were wasting time—that the problems involved in building lunar rockets already have been studied to death.

The committee is co-chaired by Dr. Nicholas Golivan, an assistant to the associate administrator of NASA, and by Dr. Larry Kavenau, an assistant to Defense Secretary Robert S. McNamara. Its recommendations are expected to set national policy on space boosters for years to come—including not only the vehicles needed by NASA but those required to support the Air Force's *Dyna-Soar* and manned space station programs.

Moreover, the committee is to report on "roles and missions" in the manned space program, the overall cost and its economic impact upon industry, and the degree to which industry is ready to undertake the enormous task.

• **Plans for $35 billion**—On the point of economics, Webb told a National Press Club audience that NASA's space activities will pour some $35 billion into the U.S. economy in the current decade.

Webb made several other disclosures about NASA plans.

He said that the U.S. will have to decide by 1965 whether to build a giant spacecraft, capable of holding 10 or 12 men, to be used for advanced lunar missions and planetary exploration. He said important space scientists believe this follow-on to the three-man *Apollo* is feasible and necessary if the U.S. is to play a major role in space.

The top civilian spaceman also said:

• Development of ground support equipment facilities is the biggest problem facing the U.S. moon effort.

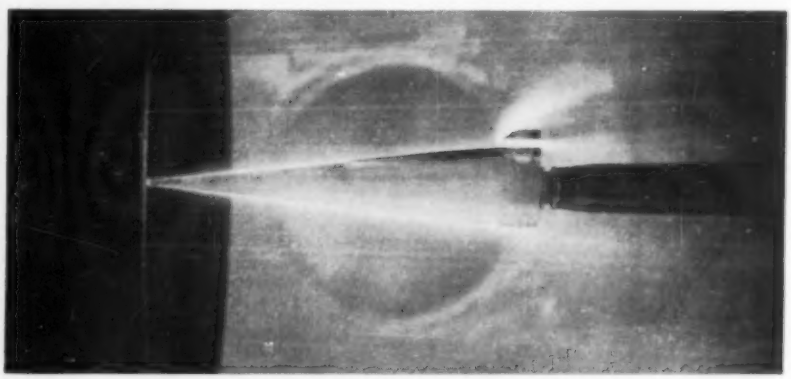
• A decision as to the location of NASA's $60-million Space Research Laboratory may be delayed because more areas are being advanced as possible sites. He indicated that the site survey team—which wound up its work last week—may be forced to survey the new areas. One is Boston's outlying "golden semicircle."

• He is no hurry to name a head for the *Apollo* program or decide on a top management setup for it. It is much more important, at this point, to make "substantive" decisions such as the award of the *S-II* contract.

• A static-firing facility will be built in the general area of the Michoud, La., plant which has been selected as the production site of the first stages of the *Saturn C-1* and *Saturn C-3*.

• **S-II plans** — The space agency said the *S-II* stage of four Rocketdyne J-2 liquid oxygen-hydrogen engines is planned as a second stage for the *C-3* version of *Saturn*. Coupled with its two 1.5-million-lb.-thrust *F-1* engines, it will be able to place a 40-ton spacecraft in a 300-mile-high earth orbit.

For missions requiring escape velocity, NASA said, a third stage with six 15,000-lb.-thrust liquid oxygen-hydro-



Republic's Mach 20 Shock Tunnel

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gen engines would be added to carry spacecraft weighing up to 15 tons.

"Tentative plans call for the use of *Saturn C-3* to place the *Apollo* spacecraft carrying three men into orbit around the moon. Manned *Apollo* lunar landings will likely await development of a *Nova*-class booster requiring a cluster of *F-1* engines in the first stage," NASA said.

Designation of a 40-ton earth-orbit capability for the *C-3* apparently means that NASA still intends to build an earth orbiting manned laboratory. Coupled to the *Apollo* spacecraft's command module, the laboratory could orbit the earth for periods up to two weeks.

North American officials said that while the exact amount of subcontracting work generated by the $140-million contract is hard to determine, it will probably be somewhere around 30% as a minimum figure.

They said that the *S-II* stages for ten *C-3* vehicles will be assembled at a new facility to be constructed on a 15-acre site at Navy Ammunition Depot, Seal Beach, Calif. Subassembly and detail production will be at NAA's Aviation Space and Information Systems Division's Downey, Calif., plant.

After *S-II* assembly, it will be moved by surface vessel from Seal Beach to Port Hueneme, Calif., a Navy construction battalion facility, and by truck from there to the Rocketdyne area at Santa Susanna for engine fitting and static test. After tests are completed, the stage will be trucked to Port Hueneme for shipment to Cape Canaveral, probably by barge. ¤

Senior members on the Golivan-Kavenau committee are:

Col. Otto Glasser and Lt. Col. David Carter, both on Gen. Bernard Schriever's staff.

H. J. Weigand, Office of AF Deputy Chief of Staff/Development.

Frank Williams and Wilson Schramm, both of NASA Marshall Space Flight Center.

Kurt Stehling and Eldon Hall, both of NASA headquarters.

Dr. Harvey Hall, NASA Vehicles Div.

Aleck Bonde, NASA Langley (Space Task Group).

Warren Amster, Edward Barlow and R. Brown, all of the Aerospace Corp.

Capt. L. J. Stecker, on the Chief of Naval Operations' staff and alternate for Rear Adm. Levering-Smith.

AF Moves Toward Bigger Profit Prospects

THE AIR FORCE is clearing the way for possibly higher profits on defense contracts.

This is in line with DOD support for such a plan as discussed at a June meeting of the National Security Industrial Association in Washington (M/R, June 26, p. 16).

Maj. Gen. William T. Thurman, Director of Air Force procurement, said that his headquarters "will favorably consider requests to exceed Armed Services Procurement Regulations limitations on fees." He said this applies to Air Force Systems Command and Air Force Logistics Command.

Thurman cited statements by both Secretary McNamara and Thomas D. Morris, Assistant Secretary of Defense (installations and logistics), supporting such action at DOD level.

Facilities Bill Clears House

The House last week narrowly passed a compromise $940-million military construction bill including $27 million in additional missile and space facilities.

The bill still must clear the Senate.

The $27 million was added to the bill by President Kennedy in his May revision of the budget. Nearly half—$12 million—is for the Air Force solid superbooster program.

A special restriction written into the bill requires that specific approval must be obtained from the House and Senate Appropriations Committee before the $12 million can be obligated.

Weather Satellite Cost

Congressional testimony has disclosed that the cost of the Weather Bureau's program for developing a weather satellite is expected to run at about $75 million a year for the next few years.

The figure for FY '62 is $53 million, but it is expected to jump to the $75 million level for FY '63—and stay there.

The present program calls for orbiting four more *Tiros* satellites before beginning the launching of the follow-on *Nimbus* weather satellites.

The breakdown for the $53 million: $38 million for satellites and launching; $12.3 million for a data acquisition station near Washington, D.C.; $2.6 million for data processing and management. The breakdown for the future $75 million: $50 million for operation of the system; $25 million for support.

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contracts

NASA

$81,240—**Ling-Temco-Vought, Inc.**, Garland, Tex., for testing effects of space flight environment on *Saturn* instrumentation and for analysis of vibration in the *Saturn* space vehicle (two contracts).

MISCELLANEOUS

$2,286,751—**Raytheon Canada, Ltd., a subsidiary of Raytheon Co.**, Lexington, Mass., for production of countermortar radars for the Canadian Army.

$350,000—**Packard Bell Electronics**, Los Angeles, from French firm **SEREB (Société pour l'Etude et la Réalization d'Engines Balistiques)** for production of an automatic checkout system for a ballistic missile.

$170,000—**Daystrom, Inc.**, Pacific Div., Los Angeles, for follow-on production of special gyroscopes for **Aerojet-General** sounding rockets.

General Electric's Missile and Space Vehicle Dept., Philadelphia, from **Lincoln Laboratory of Massachusetts Institute of Technology**, for a *Trailblazer II* fourth-stage payload capsule that will powerdive toward earth from 190-mile altitudes as part of re-entry physics studies. Work is being done for Advanced Research Projects Agency.

NAVY

$2,383,000—**Raytheon Co.**, Lexington, Mass., for added production of **AN/SPG-51** fire control systems for use with shipborne *Tartar* missile.

$1,000,000—**Transdata, Inc.** El Cajon, Calif., from **Tele-Tronics Co.**, for manufacturing single sideband receivers AN/WRR-2 and AN/FRR-59.

$700,000—**Matthews Corp.**, Hawthorne, Calif., for production of advanced-design motor tubes for the *Sidewinder* missile.

$192,000—**Western Electric Co.**, New York City, for technical support to Bureau of Naval Weapons in connection with the Weapon Direction Equipment aspects of Naval Tactical Data System evaluations and tests, and aspects of feasibility studies and planning for new designs and improvements of *Terrier* and *Tartar* ship installations.

$163,580—**Texas Instruments, Inc.**, Dallas, for ten IP-414A/APA-125 azimuth and range indicators, and 450 transistorized voltage regulator retrofit kits.

$63,357—**Arinc Research Corp.**, Washington, D.C., for investigation of electrical parts failure data collected on guided missiles from the Naval Ordnance Laboratory, Corona, Calif.

$31,032—**The Martin Co.**, Orlando, Fla., for furnishing a technical and management team for the *Bullpup*-NATO Project.

ARMY

$37,000,000—**Raytheon Co.**, Lexington, Mass., for work to be performed on the *Hawk* missile system.

$4,800,000—**The Martin Co.**, Orlando, Fla., for maintenance on Missile Master Air Defense Systems and installation of the smaller BIRDIE system.

$4,576,000—**Research Analysis Corp.**, Bethesda, Md., for operations and research.

$2,980,000—**Bendix Corp., Bendix Systems Div.**, for work connected with the *Advent* communications satellite.

$1,582,824—**Avco-Everett Research Laboratory**, Everett, Mass., from **Bell Telephone Labs.** for conducting a program associated with the development of identification techniques for the *Nike-Zeus* A-ICBM system.

$300,000—**United Telecontrol Electronics, Inc.**, Asbury Park, N.J., from Signal Corps, for development and production of transponder sets used as tracking aids in drones.

$257,831—**Firestone Tire & Rubber Co.**, Los Angeles, for missile field engineering services.

$190,848—**Gilfillan Brothers, Inc.**, Los Angeles, for *Corporal* equipment and components.

$123,806—**Aerojet-General Corp.**, Downey, Calif., for warhead and booster.

Ryan Aeronautical Co., San Diego, from Transportation Research Command, for prototype engineering for several configurations of flex-wing unmanned towed gliders. No amount disclosed.

AIR FORCE

$1,096,750—**Lockheed Aircraft Corp.**, Sunnyvale, Calif., for electronic signal studies.

$46,000—**Astropower, Inc.**, Costa Mesa, Calif., from Flight Test Center, Edwards AFB, for design and production of watercooled propellant injectors for use in experimental rocket engines.

The Siegler Corp., Hufford Div., El Segundo Calif., from **Aerojet-General Corp.**, for production of the cylindrical parts of the rocket motor case for the second stage of *Minuteman* ICBM. No amount disclosed.

Republic Aviation Corp., Farmingdale, N.Y., for a comprehensive investigation leading to improvement of structural design requirements for aerospace vehicles. No amount disclosed.

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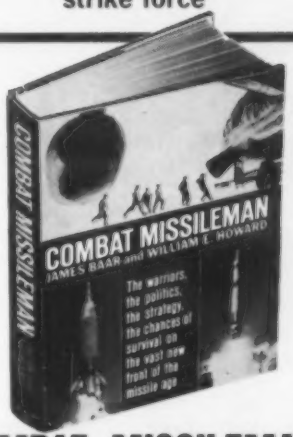
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editorial . . .

Wanted: Faith in Free Enterprise

THOSE members of the industry providing ground support equipment for the missile and space programs face a clear challenge.

Part of it was spelled out by NASA Administrator James E. Webb in a speech last week at the National Press Club. He made it very plain that the pacing item in the vast *Apollo* program will be GSE.

If anything is to delay the take-off of the first lunar expedition beyond the earliest hoped-for date, Mr. Webb said, it will be the availability of facilities.

This is no surprise in view of the size and extent of the facilities required to support a manned expedition to the moon. Picture, for example, the gantry required for a *Nova* vehicle. It weighs nearly 4000 tons and towers 435 feet into the air. The industry has never before attempted anything like it.

Or imagine the facility needed for environmental checkout of an *Apollo* vehicle; advanced computers which will speed up the countdown; the handling equipment required for boosters of *Saturn* and *Nova* size.

Imagination is just what it takes to see this equipment. It does not exist. It must be designed, approved, built and tested. In some cases, the requirements don't even exist—because we don't yet know what they are.

Somewhere along the way, someone will have to spot the requirements, verify them, draw up specifications, call for bids, appraise proposals and let contracts.

All of this on a timetable which demands that the facilities and equipment be ready when the spacecraft and booster are ready to go. It is a task which staggers the boldest planner.

The fact that Administrator Webb has recognized the importance of GSE to the lunar program—and has, in fact, labeled it as the pacing factor—is a giant step in the right direction. Recognition of the problem by the man at the top is a mighty important aid to solving it. Too frequently, concern over GSE is left until too late for it to be anything but a problem; witness the troubles in the ICBM base program.

Recognition alone is not enough, however. The approach NASA takes to the solution will have a strong bearing on the success of the *Apollo* program. Once a GSE problem area is discovered, it should be passed to industry for solution—with a minimum of government interference.

The members of the missile/space industry who are in the GSE field are a remarkably independent lot, from the roughneck contractor responsible for site construction to the scientist tinkering in his electronics lab with a new computer circuit.

NASA must have faith in their ability to meet the goals which are set. This is true not only in GSE but in all aspects of our space program. Industry must be allowed sufficient initiative to strike out boldly after objectives, and enough freedom to take the necessary risks. The lunar program is too big to be bogged down with bureaucratic procedures. If that happens, its vast size is a guarantee that it will collapse.

Freedom is our way of life and free enterprise is our system. NASA should demonstrate its belief in both.

Administrator Webb went on record with a breakdown of funding—80% to industry and 20% for in-house capability—that indicates he intends to rely heavily on industry management in various areas of the lunar program. We applaud the implication. We will, however, keep a skeptical eye on that 20%.

IMPORTANT AS IT IS, space is not the only challenge to GSE manufacturers today. Resumption of nuclear testing is bringing with it a complete reappraisal of missile GSE. Bigger bombs mean a new look at hardened-site requirements. Bigger bombs also mean new importance for mobile systems, airborne as well as ground.

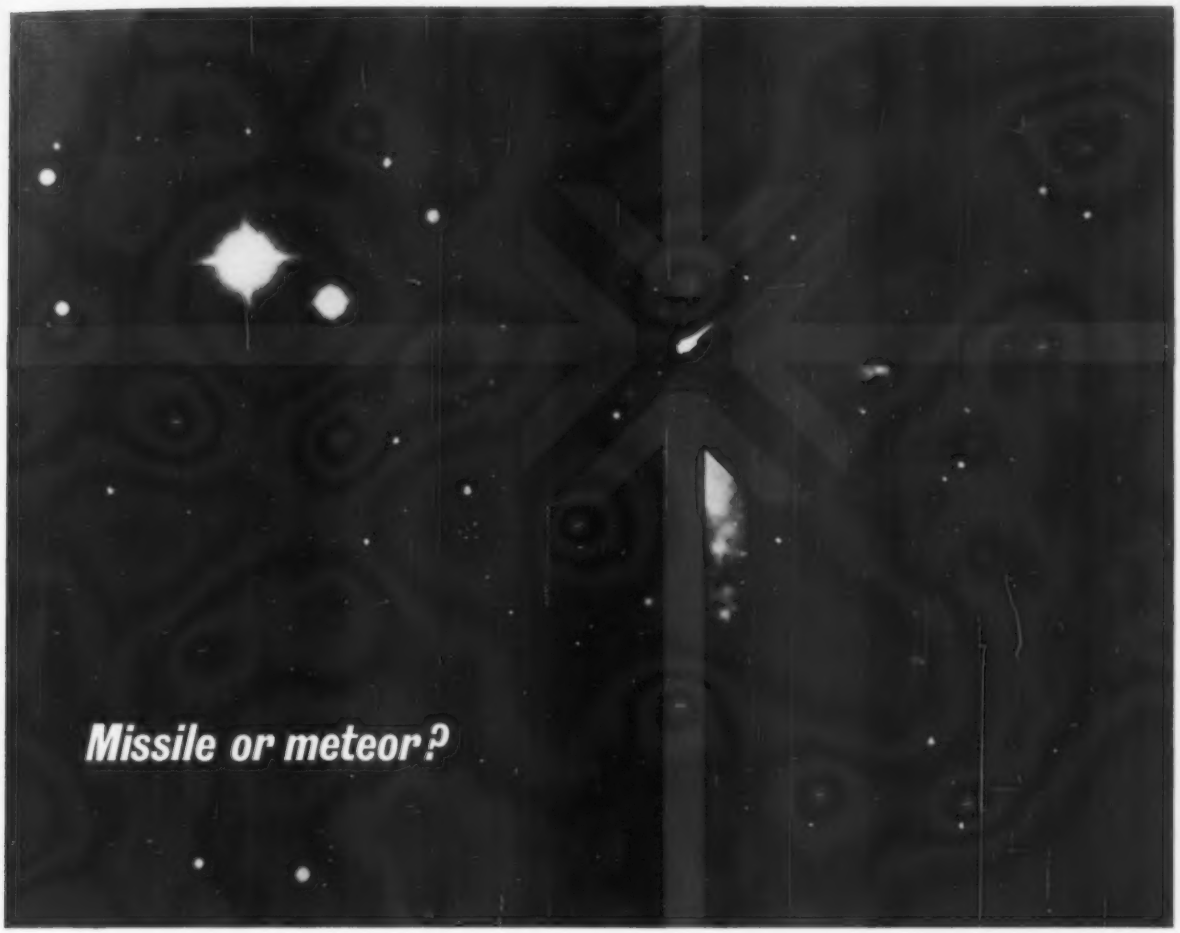
All of this adds up to sudden revival of a market for which many forecasts have been on the gloomy side. With completion of the *Atlas* and *Titan* programs only a few years off, financial prophets have been bearish on GSE prospects.

That has changed abruptly since the first of the year. President Kennedy's decision to back the *Apollo* program as a prime national objective, taken with the new emphasis on missile GSE, brightens the 1961 market outlook.

Up to 50% of spending on missile/space programs over the next five years will be in the GSE field. In dollar terms, it will rise far above the current GSE outlay of $4 billion to $6 billion a year.

This brighter outlook carries with it both problems and responsibilities. We are confident our GSE makers can handle both. They should be given both —not just the problems.

William J. Coughlin



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